STUDENTS TEXTBOOK OF HYGIENE

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STUDENT'S TEXTBOOK OF HYGIENE

STUDENT'S TEXTBOOK OF SURGERY

BY

H. NORMAN BARNETT, F.R.C.S.

Surgical Registrar, Royal Victoria Hospital; Surgeon, Cripples' Institutes for Ireland, Belfast; Surgical Assistant, Belfast Hospital for Sick Children.

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BY

W. JAMES WILSON, M.D., D.Sc., D.P.H.

BACTERIOLOGIST TO THE COUNTIES OF DOWN AND ANTRIM
LECTURER IN HYGIENE AND PUBLIC HEALTH, QUEEN'S UNIVERSITY, BELFAST

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PREFACE

This book is based on a course of Lectures which I have given during the past seven years to the Hygiene class in the Queen's University, Belfast. It is therefore specially written to meet the requirements of students of medicine, but it is hoped that it may also prove useful to teachers, sanitary inspectors, health visitors, and all who are interested in Public Health.

In a subject of such wide range as Hygiene, even with judicious selection, it is impossible in a Student's Textbook to do more than deal with the principles of the science, and to indicate their application. The details of the methods employed in the analysis of Water, Food, Air, etc., and of the procedure required in Public Health administration, are omitted, since these can be properly learnt only in the Laboratory and in the Office of the Medical Officer of Health. I have, however, given sufficient information to enable the student to appreciate the meaning and value of the results of analyses, and to understand the responsibilities resting upon the Medical Officer of Health, the general medical practitioner, and the private individual, with regard to the preservation of Health and the Prevention of Disease.

In writing the book the best-known English and foreign Textbooks on Hygiene and Medicine have been consulted.

I am indebted to Dr. H. P. Malcolm for photographs, from which Figs. 24 and 25 have been prepared. The source of the other figures is acknowledged in the text.

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STUDENT'S TEXTBOOK OF
HYGIENE

CHAPTER I

INTRODUCTION

Hygiene is that branch of medical science which deals with the preservation of good health and the prevention of disease. Sometimes the terms Preventive Medicine, Public Health, and Sanitary Science are used as if they were synonymous with Hygiene; but the latter deals with the principles of the science, whilst the others deal with the application of these principles in practice. To fully understand the subject of Hygiene, some acquaintance with such diverse sciences as physics, chemistry, physiology, geology, engineering, architecture, meteorology, epidemiology, biology, and statistics, is necessary. Of all these sciences, the one which has most influenced the subject of Hygiene is that recent offshoot of biology—bacteriology. In fact, it is absolutely impossible to understand the subject unless one is thoroughly familiar with the rôle bacteria play in the most varied processes of organic nature.

We believe that the following short sketch of the development of the germ theory of disease will show that this theory has revolutionized modern medicine, and, of course, as a result, modern hygiene.

The student will then appreciate that hygiene does not simply consist in the study of air, water, and soil, the ventilation of rooms, and the principles underlying the building of drains, sewers, and ashpits; but that it has a far wider province, and that every day extends the domain of this science.

This extension has necessitated specialization in its study,

so that separate treatises have been written on such matters as infectious diseases and their prevention, vital statistics, sanitary law, personal and school hygiene, industrial hygiene, military and naval hygiene, sanitary engineering, public health chemistry and bacteriology.

In this book merely the principles of the science are considered, and for this consideration bacteriology is the "open sesame." Pasteur's work brought hope to humanity in its conflict with disease. In the following words of Tyndall we have a tribute paid to this work: "We have been scourged by invisible thongs, attacked from impenetrable ambuscades, and it is only to-day that the light of science is being let in upon the murderous dominion of our foes." Pasteur and Koch have left the scene, but their torches have been passed on to worthy hands in different lands, and the mere mention of such names as those of Metchnikoff, Ehrlich, Wassermann, Wright, and Flexner, reminds us that mankind in this struggle has still valiant protagonists.

GERM THEORY.—The germ theory of disease has been before the medical world for about seventy years, but it is only during the last generation that it has attracted much attention and has firmly established itself. Let us briefly glance at the views held regarding disease which the germ theory has supplanted.

One of the earliest of these, and one which is still widely held by savage tribes, attributes disease to the activity of an evil spirit or demon which has entered into and possessed the body of its victim. This **animistic or demonistic conception** of disease still finds expression in the practices of the "medicine-man," who endeavours, by incantations and in other ways, to exorcise the demon. As regards one large class of diseased persons—the insane—the theory of demoniacal possession has remained current for obvious reasons up to comparatively recent times.

With the progress of civilization and culture more scientific theories were advanced. Of these the **Hippocratic**—named after its founder, Hippocrates, the father of medicine—predominated all through the Middle Ages, and vestiges of it are still seen in some common medical terms. According to this theory, the

body contains four humours—Blood, Phlegm, Yellow Bile, and Black Bile. According to the admixture of these four humours, the health, or absence of it, was determined. Accordingly, we get the terms "sanguine," "phlegmatic," and "melancholic," used to describe the temperament of the individual. In acute diseases the humours went through a regular process, being first of all crude, then passing through coction or digestion, and finally being expelled by resolution or crisis through one of the natural channels of the body. According to this theory, therefore, the efforts of the physician or hygienist should be directed with the object of restoring or preserving the normal proportion of the humours.

It was only in the seventeenth century that the truth of this theory was seriously questioned, and an attempt made to replace it by other theories, which in many cases were more complex and mystical than the original. Some of the attempts to define disease will show how words were used as a mere cloak for ignorance. Thus, "Disease is an intestine movement of particles," "an attempt of Nature to eliminate morbific matter," "a want of tone," "a deficiency of stimulus," and so on. Perhaps the most typical of these definitions is that given by Hahnemann, the founder of Homeopathy: "Disease," said this writer, "is a spiritual dynamic derangement of a spiritual vital principle."

Hahnemann maintained that medicines gained in strength by diluting, if the dilution was accompanied by shaking. His treatment in many cases was successful, and probably under his direction the "vis mediatrix Naturæ" had a greater chance of asserting itself than under physicians giving enormous doses of the most incongruous mfxtures of drugs.

Whilst these theories continued to be held by the medical schools, the introduction of the microscope was preparing the way for the modern Germ Theory of disease. In 1675 Leeuwenhoek, a Dutch observer, discovered in rain-water, saliva, and diarrhœal evacuations, living mobile micro-organisms, to which he gave the name of "animalculæ." From his descriptions and drawings there is no doubt that Leeuwenhoek was the first to see living bacteria. A great advance was made when Marcus Antonius Plenciz, a Viennese physician, in 1762, pro-

pounded the view that all infectious diseases were caused by living micro-organisms. By very acute reasoning he showed how such a view would explain the incubation period of different diseases. Plenciz believed that for each specific disease there was a specific micro-organism; and he also suggested the possibility of the air acting as a medium for conveying the infective agent.

Plenciz's theory obtained notable support from the publication of "Pathological Investigations" by Henle in 1840. Henle showed that the view that an infective disease was due to a living entity harmonized with the phenomena presented by the rise and fall of epidemics. Plenciz and Henle adduced no experimental support for their views, although such was available in Henle's time, since Bassi had, in 1835, shown that a fungus was the cause of Muscardine—a fatal disease of silkworms—and in the common skin diseases Favus and Ringworm, fungi had already been demonstrated.

In 1847 Semmelweiss attributed the puerperal fever of lying-in women to infective material introduced on the fingers of the accoucheurs—a view received with ridicule by the medical teachers of that period.

Three men divide the honour of having established the fact that anthrax was due to infection with a definite bacterium.

It was shown by Pollender in 1849, and by Davaine in 1850, that in the blood of animals dying from this disease rod-shaped organisms (*Bacilli anthracis*) were present, and in 1863 Davaine transmitted the disease to other animals by inoculating them with blood containing these bacteria. That the *B. anthracis* was the true cause of anthrax was definitely proved when, in 1879, Koch obtained pure cultures of the bacillus and succeeded in causing the disease as readily by inoculation with these cultures as with the blood of an animal recently dead from the disease.

It was probably the striking results obtained by **Lister's antiseptic treatment** of wounds that more than anything else caused the recognition of the parasitic theory of disease. Lister's system rested on the germ theory of fermentation and putrefaction established by Pasteur, after years of experiment, in 1862.

What were the views regarding fermentation and putrefaction held prior to Pasteur's work? It was a matter of common observation that organic matter readily putrefied, and, in the case of meat, that this putrefaction was often accompanied by the appearance of maggots. Ancient writers such as Lucretius believed that these were instances of **spontaneous generation**—that is to say, of living organisms being born from non-living matter. In fact, this was the common view not only of antiquity, but down through the ages till the middle of the seventeenth century. Redi, by a simple experiment, proved that the maggots were really developed from eggs deposited by flies on the meat, and that if flies were excluded, no maggots appeared on the meat.

Spallanzani demonstrated that the boiling of putrescible infusions of organic matter contained in hermetically sealed flasks prevented putrefaction.

It was objected to this experiment that the exclusion of air prevented the occurrence of spontaneous generation; but this was answered by Schulze in 1836, who allowed air to enter the flasks after it had passed through strong sulphuric acid, and still no putrefaction occurred.

Schwann, in 1839, established the same fact by passing in air through a heated tube. To Schwann also is due the credit of having discovered the specific cause—the yeast-plant—of alcoholic fermentation.

At a later period Schroeder and Von Dusch showed that putrescible liquids sterilized by heat could be kept indefinitely in flasks the mouths of which had been closed with cotton-wool, the latter acting as a filter for the removal of bacteria from the entering air. It was, however, the careful work of Tyndall and Pasteur that gave the death-blow to the theory of spontaneous generation, at any rate so far as it applied to putrefaction and fermentation—the former by his well-known investigations on the floating matter of the air and his demonstration of the living character of much of it, the latter by showing that putrefaction occurring after apparent sterilization was due to the possession by certain bacteria of resistant bodies known as "spores."

When Pasteur had firmly established the fact that fermenta-

tion and putrefaction were due to micro-organisms, Lister conceived the idea that the suppuration of wounds could be explained on similar lines, and could be prevented by the use of antiseptics and germicides. Attention had been drawn to the presence of minute bacteria in the matter discharged from abscesses by Rindfleisch in 1866, and Waldayer and Von Recklinghausen in 1871.

Lister's work was done in the years between 1865 and 1874, and was inspired by that of Pasteur. Lister always gratefully acknowledged the stimulus given to him by the French chemist, as is shown by the following extract from a letter written by him to the latter in 1874 :

" Allow me to take this opportunity to tender you my most cordial thanks for having by your brilliant researches demonstrated to me the truth of the germ theory of putrefaction, and thus furnished me with the principle upon which alone the antiseptic system can be carried out."

It was owing to Lister's influence that modern surgery has won such triumphs in the treatment of disease, and it is only by reading accounts of the terrible mortality attending comparatively simple operations in pre-antiseptic times that we of to-day can appreciate the boon conferred on humanity by the beneficent work of Pasteur and Lister.

Since 1880 investigations carried out in every quarter of the globe have resulted in the demonstration that practically all known infectious diseases are due to the attacks of parasites belonging either to the vegetable or animal kingdom. The view that the parasites found in these diseases are the cause of the same should be regarded rather as a scientific fact than as a mere theory.

At the present time the questions being investigated are, What are the factors concerned in the defensive and offensive powers of the host and parasite? The parasite may be compared to a seed, and the host to the soil on which it is sown, and the varying characters of both these will account for all the phenomena of a disease.

Within recent years the work of clinical pathologists has shown that the great majority of non-communicable diseases are also due to microbic invasion. In order that a disease

should be attributed to a definite micro-organism certain conditions—**Koch's Postulates**—should be fulfilled. (1) That the same microbe should be found invariably associated with the disease in question, being present in the blood or affected tissues; (2) that it should be possible to obtain pure cultures of the micro-organisms; (3) that inoculation of a susceptible animal with these cultures should give rise to the same disease; and (4) in these animals the microbe should have the same relation to the tissues as in the naturally diseased animal.

In many cases it is impossible to satisfy all these requirements, since the lower animals are often immune to human diseases. Still, in such cases, experiments on lower and higher apes have enabled investigators to study the conditions under which the virus may be transmitted. In fact, in order to definitely establish a proof that a microbe is the cause, and the only cause, of certain infectious diseases, a fifth postulate may have to be complied with—viz., that when an animal is inoculated with the true infective agent, the disease so acquired will spread to other similar susceptible animals in the same way as the natural disease spreads.

The importance of this postulate was shown in the study of Hog Cholera. In this condition a bacillus—*B. suispestifer*—was invariably found in the blood and tissues of the diseased animals, and the blood-serum of these animals exercised a specific agglutinating action on the micro-organism, and inoculation of healthy swine with pure cultures of this bacillus gave rise to a disease apparently similar to the natural disease; but, unlike the latter, healthy animals in contact with the inoculated animal did not become infected. It was shown by Dorset, Bolton, and MacBryde that the virus of this disease existed in serum that had passed through a Berkefeld filter, and from which no bacterial growth could be obtained, the virus in question being a filter-passer, or ultra-microscopic. When a healthy animal was inoculated with such serum, it became infected with Hog Cholera, and this spread to other swine brought into contact with it. Later investigations showed that the *B. suispestifer* is present in the intestine of healthy animals, and that in swine fever it is a mere secondary

invader, the resistance of the body to its entrance from the alimentary canal being lowered in this disease.

From this survey we see on what a firm basis of truth the germ theory rests, and that in combating disease it is necessary to accurately know the conditions favourable to the survival and multiplication of bacteria inside and outside of the body. It has been found that the nature of the environment in which a person lives and of the food he eats, as well as his inherited qualities, are important factors in determining whether he will fall a victim to or overcome an attacking bacterium. Hygiene therefore requires the study of heredity, of food, of air, soil, and water, of infectious diseases and immunity, and of the construction and sanitation of dwellings and towns.

In order to improve and preserve the health of the people sanitary laws have been enacted, and for their administration a staff of Officers having a special knowledge of Hygiene has come into existence. It may be said that the Public Health movement started in England in the early years of the nineteenth century, and that the Report of Chadwick on the Sanitary Condition of the Labouring Population (1842), which was the result of Lord John Russell's commission in 1839, marked an epoch in the sanitary and social history of this country. We see, then, that before the germ theory had been established, the effects of filth and overcrowding in the dissemination of disease had been perceived and appropriate remedies sought.

The advances made by bacteriology in modern times have more precisely indicated the special measures required in each disease.

That the efforts made in the interests of Public Health have not been in vain is shown by vital statistics. Three centuries ago London had a death-rate of 80 per 1,000, whereas to-day it is less than 14. The advances that are being daily made in preventive and curative medicine, and the improvements being effected in the social conditions of the people, will not fail to bear fruit in a still further reduction of the mortality-rate and an increase of general comfort and happiness.

PLATE I.

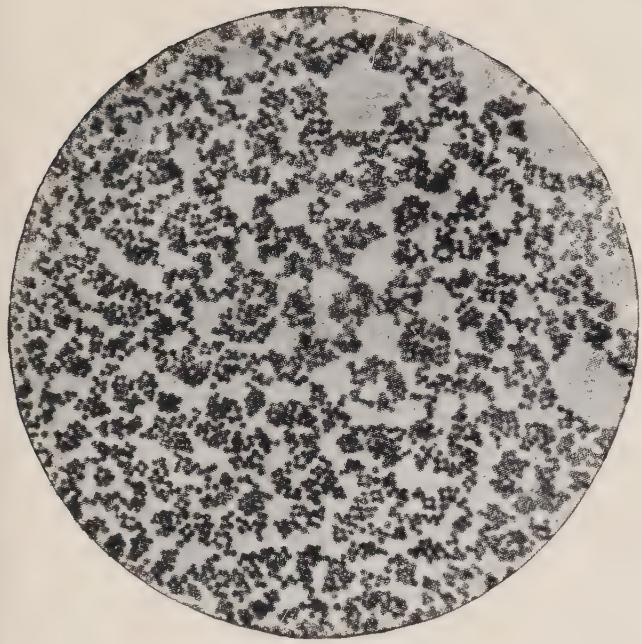

Fig. 1.—*Staphylococcus pyogenes aureus.* ×1000.

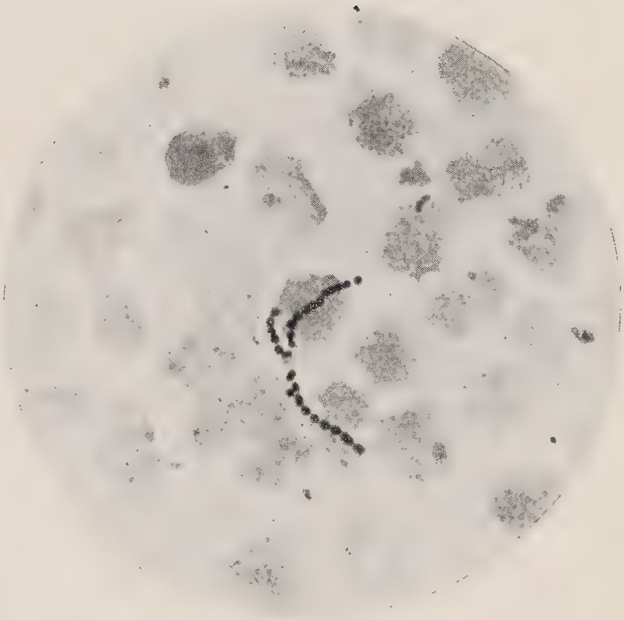

Fig. 2.—*Streptococcus pyogenes* in Pus, Gram's stain. ×1000.

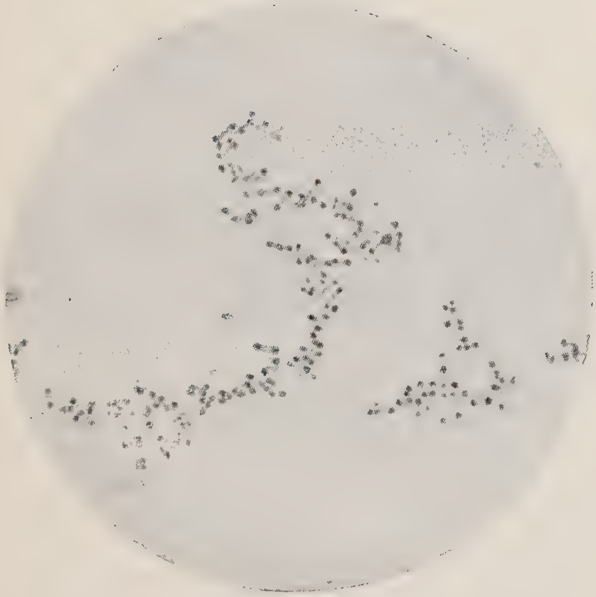

Fig. 3.—*B. diphtheriæ*, Neisser's stain. ×1000.

(*From* Williams' "Bacteriology.")

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CHAPTER II

INFECTION AND IMMUNITY

THE INFECTIVE AGENT.—Apart from animal parasites belonging to the class of Vermes and Arachnida, it may be said that the Bacteria, Protozoa, and filterable Viruses are the living entities responsible for infection.

Bacteria are unicellular, microscopic particles of protoplasm belonging to the vegetable kingdom. They are destitute of chlorophyll, and reproduce themselves by a process of fission, and hence are sometimes termed **schizomycetes.**

In certain cases specially resistant, highly refractile round or oval reproductive bodies known as **spores** are produced. Such spores are exceedingly difficult to kill by the action of chemicals, and will even withstand a temperature of 100° C. for some hours. In favourable conditions the spores germinate and grow out into bacilli. Fortunately, the majority of pathogenic bacteria do not form spores. Bacteria vary greatly in size and shape, and, according to the latter characteristic, are classified as follows:

1. **Micrococci.**—Minute spherical bodies, usually 0·5 to 1 μ in diameter. These multiply by fission, and, according to the direction of the plane in which this occurs, different grouping results—*e.g.*, cocci in pairs = **diplococci,** in chains = **streptococci,** in clusters = **staphylococci.**

2. **Bacilli.**—Rod-shaped bodies, on an average 3 to 6 μ in length, with square or rounded ends. Many of these are actively motile, locomotion being produced by the movement of hair-like threads—flagella or cilia—attached to the bacillus.

3. **Spirilla or Vibriones.**—Long, slender, wavy threads twisted on their long axis, capable of free movement. Some of these readily break up into shorter elements, which consist of slightly

curved motile Vibriones—*e.g.*, Koch's spirillum of cholera—sometimes called the "comma bacillus," from its resemblance to the German comma.

Spirochætes are micro-organisms morphologically similar to Spirilla, but which are exceedingly difficult to cultivate, and which are regarded by many as belonging to the class of the Protozoa rather than to the Bacteria. In favour of this view is the statement that reproduction is effected by longitudinal division, whereas among bacteria it is invariably along a transverse axis that fission occurs. To this group belong the spirillum, or by preference the Spirochæte of Obermeier and the *Spirochœta pallida*, the cause of Relapsing Fever and Syphilis respectively.

4. **Higher Bacteria** include long, unbranched (**leptothrices**) or branched (**streptothrices**) threads, which reproduce themselves by shedding off conidia from terminal filaments. The lesions produced by streptothrices, of which Actinomycosis is an example, have a resemblance to those produced by the tubercle bacillus, and, indeed, the latter micro-organism is closely allied to this class of bacteria.

Protozoa.—Unicellular, microscopic parasites belonging to the animal kingdom. These play an important rôle in the etiology of many Tropical Diseases. They are usually classified into four groups:

1. **Rhizopods,** of which *Amœba dysenteriæ,* the cause of one form of Dysentery in man, may be taken as an example. Movement is effected by the protrusion of finger-like masses of protoplasm (pseudopodia). Reproduction results from fission, but in some cases spores are formed.

2. **Sporozoa.**—In this group sporulation or breaking-up of the individual into a number of spores at one stage of its existence is an outstanding characteristic. An important example of this group is the *Plasmodium malariæ,* which, like other members of it, has a very complex life-history, one stage of its development being passed in the body of an insect, the other in the blood of the malarial patient.

3. **Flagellates,** characterized by the possession of a long flagellum, are long, more or less spindle-shaped Protozoa, with a macronucleus and a micronucleus or blepharoplast, from the

PLATE II.

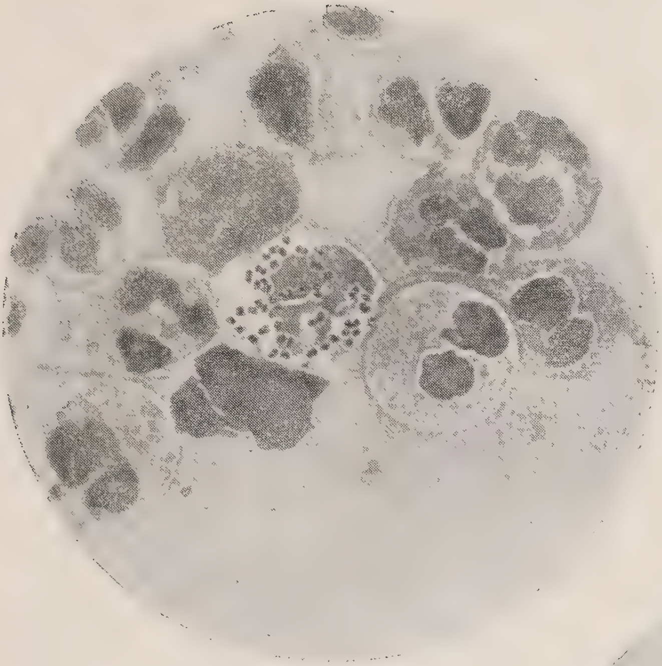

FIG. 4.—Gonococci and Pus Cells. ×1000.

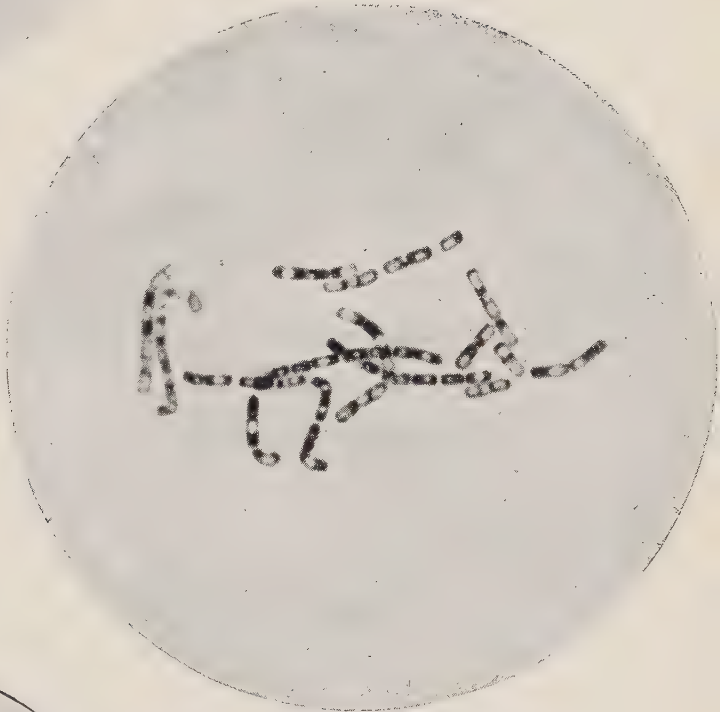

FIG. 5.—Anthrax Bacilli, showing Spores. ×1000.

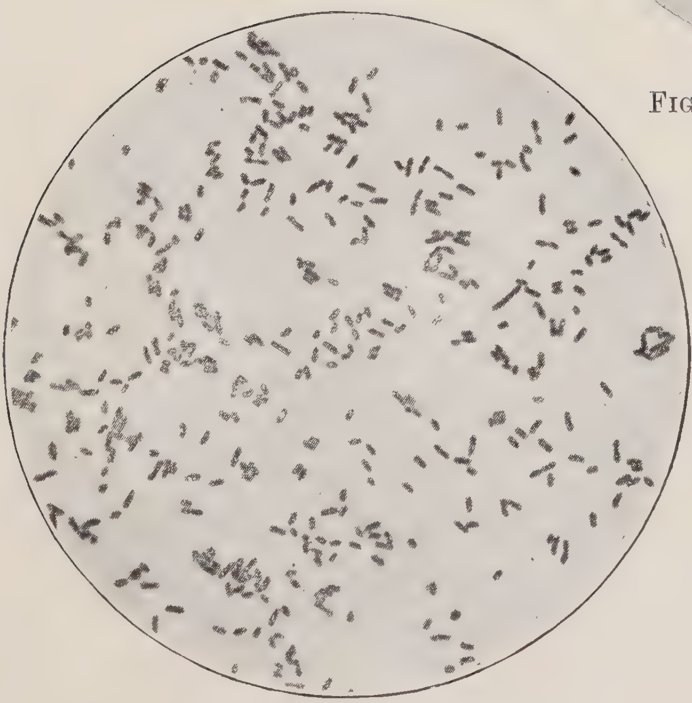

FIG. 6.—*B. coli communis.* ×1000.

(*From* Williams' "Bacteriology.")

PLATE III.

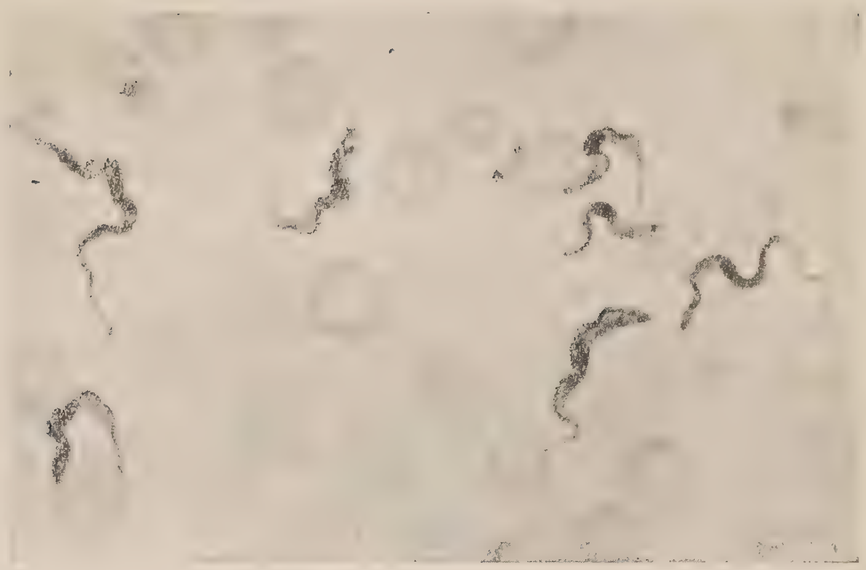

FIG. 7.—*T. gambiense*, from the Blood of a case of Sleeping-Sickness. × 1000.

(*From* Beattie and Dickson's "General Pathology.")

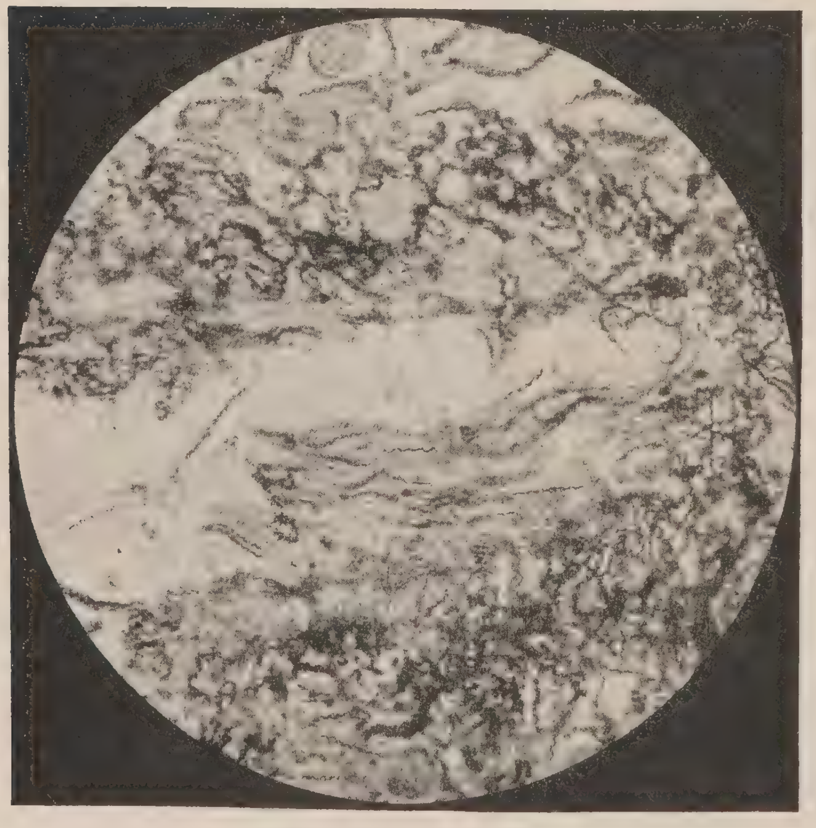

FIG. 8.—Spleen from a case of Congenital Syphilis, showing numerous *Spirochætæ pallidæ*. × 1000.

(*From* Beattie and Dickson's "General Pathology.")

latter of which the flagellum takes origin. Along the side of the parasite there is an undulating membrane. The pathogenic trypanosomes, such as the *Trypanosoma gambiense,* the cause of Sleeping Sickness, have a complicated life-cycle, one stage being passed in the blood of the infected animal, the other in the gut of a biting fly.

4. **Infusoria.**—Free-swimming protozoa surrounded with a mantle of cilia. Paramœcium is a well-known example of this class, varieties of which have been regarded as the cause of certain forms of diarrhœa.

Filterable Viruses.—Within the last few years the study of filterable viruses has thrown a flood of light on the etiology of many diseases of man and of animals. These are micro-organisms which will pass through filters whose pores are too small to allow of the passage of ordinary bacteria. Such filters are the well-known Berkefeld filter made of diatomaceous earth, and the Chamberland filter, made of unglazed porcelain. The term "ultra-microscopic" is often used as synonymous with filterable, but all filterable viruses are not at every stage of their development ultra-microscopic. At the present time some thirty different diseases of men and animals have been attributed to filterable viruses.

Of these the best known are—Yellow Fever, Dengue Fever, Sand-Fly Fever, Typhus Fever, Poliomyelitis, Rabies, Variola and Vaccinia, Measles, Scarlet Fever, Trachoma, Foot-and-Mouth Disease—Cattle Plague—Hog Cholera, and Pleuro-Pneumonia of cattle.

The chief characteristic of the filterable viruses is that the majority of them are destroyed by heating to a temperature of 50° to 70° C. for ten minutes, and that they are resistant to the action of glycerine and the process of desiccation. In some cases the virus is transmitted by an intermediate host—a biting insect of some sort—*e.g.*, Yellow Fever and Dengue Fever by a mosquito, Sand-Fly Fever by a midge (Phlebotomus), Typhus Fever by a body-louse. In other cases an abrasion of the surface of the body allows of the entrance of the virus—*e.g.*, Rabies. A few diseases, again, are contracted through contact with infective discharges—*e.g.*, Pleuro-Pneumonia of cattle and Cattle Plague, whilst others are probably air-borne—*e.g.*,

Variola, Scarlet Fever, Measles, Foot-and-Mouth Disease, and Hog Cholera.

Disease in general may be regarded as a poisoning of the cells of the body, and in the great majority of cases this poisoning is the result of the attack of a micro-organism. In the diseases that are called infectious, the infective agent under suitable conditions can be transmitted to susceptible persons in the neighbourhood of the patient. Many factors determine this **susceptibility,** and of these the most important are—(1) The age and general state of health of the individual; (2) the question whether he has had a previous attack of the disease, or has been artificially immunized against it; and (3) the absence or presence of hereditary predisposition.

MODES OF INFECTION.—Disease is as a rule contracted by the infective agent gaining admission to the body by (1) inhalation, (2) ingestion, or (3) inoculation through the skin. The specific bacteria usually derived from the secretions, excretions, desquamated epidermis, or in certain cases from the blood of the infected, are conveyed to the healthy by the following vehicles or vectors:

1. By the **air**—*e.g.*, in Pulmonary Tuberculosis, Variola, Chicken-Pox, Diphtheria, Scarlet Fever, Measles, Mumps, Whooping-Cough, Influenza, Pneumonic Plague. Small particles of mucus and sputum are sprayed into the air surrounding the patient when he coughs or speaks. It is probable that during quiet breathing the breath is not infectious.

Certain bacteria can resist desiccation, and dust containing such may be a source of disease—*e.g.*, *B. anthracis* in Wool-Sorter's Disease, tubercle bacillus in Pulmonary Tuberculosis.

2. By **water.** Examples of diseases that may be water-borne are Enteric Fever, Cholera, Dysentery, and various Worm diseases.

3. By **milk.** The milk itself may contain the infective agent directly derived from the cow or goat—*e.g.*, the tubercle bacillus, the virus of Foot-and-Mouth Disease, or the *Micrococcus melitensis*—or the milk may get infected through coming in contact with infective human secretions or excretions, either directly or through water contaminated with them—*e.g.*, Scarlet Fever, Diphtheria, Enteric Fever, Cholera.

4. Through **shellfish, vegetables,** etc., contaminated with infectious discharges—*e.g.*, Enteric Fever, Cholera, Diarrhœa.

5. By **meat,** which may contain living bacteria or animal parasites—*e.g.*, the tubercle bacillus and anthrax bacillus may be present in the meat, or the micro-organisms that cause food poisoning—*e.g.*, *Bacillus enteritidis* (Gaertner) and *B. botulinus*. The presence of the cystic stage of Tæniæ or of the embryonic stage of the *Trichina spiralis* may lead to the infection of the consumer with adult worms.

6. By **Fomites**—*i.e.*, clothing and other objects which have been soiled with infective matter—*e.g.*, Scarlet Fever, Measles, Diphtheria, Variola, Chicken-Pox, Enteric Fever, Cholera.

7. **Disease of a Lower Animal** may be a source of infection for man. Instances of such diseases communicable to man are—Vaccinia Tuberculosis, Anthrax, Rabies, Tetanus, Diphtheria, Glanders, Foot-and-Mouth Disease, Plague, Actinomycosis, Septicæmia, Malta Fever, and various forms of Helminthiasis.

8. Diseases conveyed by **Insects.** Malaria by various species of the genus Anopheles, Yellow Fever by *Stegomyia calopus*, Dengue by *Culex fatigans*, Sand-Fly Fever by the sand-fly (*Phlebotomus papatasii*), Sleeping Sickness by *Glossina palpalis*, Relapsing Fever by bed bugs and lice, Tick Fever by ticks, Plague by fleas, Typhus Fever by lice. It is possible that bugs convey the *B. lepræ*.

In the case of Enteric Fever, Cholera, and Diarrhœa, probably flies after contact with and feeding on infected discharges, infect food, and especially milk on which they afterwards settle. Not only is this the result of mere mechanical transference of the filth on their legs, but also because intestinal bacilli can live for several days in the crops of the flies, and can be deposited by the fly from its mouth or anus on food. Flies may also convey the eggs of animal parasites—*e.g.*, of Tæniæ, *Ascaris lumbricoides*, etc.—from excreta to food.

9. When **wounds** or pricks are caused by instruments on which pathogenic bacteria are lodged, or when dirt containing certain germs gains access to wounds, certain definite diseases may follow—*e.g.*, the *B. anthracis* and the *B. tuberculosis* may be thus inoculated, the former giving rise to a Malignant Pus-

tule, the latter to a chronic induration of the site of inoculation, usually called a "butcher's wart." Local suppuration occurs when pyogenic bacteria are introduced into wounds, and these micro-organisms may form abscesses in other parts of the body (pyæmia), or may multiply in the blood-stream, causing Septicæmia. Puerperal Fever is the result of infection of the uterus with septic bacteria. Other examples of diseases contracted by inoculation are Tetanus, Rabies, Vaccinia, and Glanders.

The term **contagious** is applied to those diseases where intimate contact with an infective discharge produces the disease in question. To this class belong the venereal diseases Syphilis and Gonorrhœa, Trachoma and purulent Ophthalmia.

Each specific disease has a specific micro-organism associated with it. We have already seen the various modes by which such micro-organisms can be conveyed from the sick to the well. At the present time it is generally believed that every occurrence of infectious diseases can be traced back to a similar disease in another man or animal. The old view—**the "de novo" hypothesis**—that decaying matter not specifically contaminated might yet give rise to such a specific disease as typhoid fever, is no longer held. It is not denied that new diseases may from time to time be evolved, but the infective agents in such cases are more likely to be saprophytes which had adapted themselves to life in various parts of the air and food canals rather than bacteria living in filth. At the present time the study of **"carriers"** is receiving particular attention, and has afforded an explanation of many outbreaks of infectious diseases, which in the old days would have been regarded as instances of *de novo* infection. It has been found that pathogenic bacteria may persist for months or years in the secretions or excretions of patients convalescent from attacks of such diseases as Enteric Fever, Cholera, Dysentery, Diphtheria, Cerebro-Spinal Fever, and Pneumonia, and that in many cases such "carriers" have been responsible for one or more outbreaks of disease. Such a carrier is called an **effective** carrier; others may carry the germs without there being any proof that they have infected others. It is well known that bacteria vary in virulence, and it is possible that it is only at certain times that the bacteria of carriers can transmit

infection. Not only do the sick and convalescent, but also in many cases those who are brought into contact with them, harbour bacteria, and these healthy carriers may transmit the disease germs and infect others less resistant than themselves.

When the virus of a disease enters the body of a susceptible person, for a time—the so-called **incubation period**—no symptoms are manifest. During this period, which is fairly constant for each disease, the micro-organism multiplies in the body, and it is only at the end of it that its presence is betrayed by the symptoms of the disease, such as rise of temperature, appearance of a rash in the case of the exanthemata, etc. The Incubation period is less than a week in Scarlet Fever, Diphtheria, Plague, Cholera, Yellow Fever, Influenza, and Erysipelas; more than a week in Variola, Varicella, Measles, Rötheln, Mumps, Enteric Fever, and Typhus Fever. A knowledge of the length of the Incubation period is important in determining the length of time necessary to isolate or supervise "**contacts**"—*i.e.*, people who have been exposed to infection.

The effects produced by each specific germ are so constant that it was on these, and these alone, until recently that the physician based his diagnosis. In certain cases the disease terminates by crisis; there is a sudden drop in the temperature and an abatement of the other symptoms, whilst in other cases this decline is gradual (defervescence by lysis).

The climatic conditions of certain portions of the world are favourable for the persistence of the disease, and in such places the disease is said to be **endemic**—*e.g.*, Cholera in the delta of the Ganges, Scarlet Fever and Diphtheria in parts of Great Britain. From such endemic centres the disease may spread or become **epidemic,** and great numbers in other districts may be attacked. When a disease extends over a large area of the globe, as occurred with certain epidemics of Influenza, it is said to be **pandemic.**

IMMUNITY.—On recovery from an infective disease, the individual for a shorter or longer period is insusceptible to a further attack, even although exposed to infection. In the case of some diseases—*e.g.*, Variola, Typhoid and Typhus Fevers, Scarlet Fever, Measles—the period of protection is long, and may last throughout life; in other cases it is short, and, in fact,

the attack seems to render the individual more susceptible to the disease in question—*e.g.*, Influenza, Pneumonia, Erysipelas. **Immunity,** or non-susceptibility to a disease, may be either **natural** or **acquired.** Certain bacteria are pathogenic only to certain species of animals, and among susceptible animals there are degrees in the susceptibility. Algerian sheep, unlike other breeds, are immune to Anthrax. The dark-skinned races suffer less severely from Malaria than Europeans, but this may not simply be due to the possession of a certain amount of natural immunity, but also to slight attacks in childhood tending to protect the adult.

Acquired immunity is usually effected (1) by an attack of the natural disease, but may also be produced in other ways; (2) by inoculation with an attenuated form of the virus of the disease. In vaccinating against Smallpox lymph obtained from calves affected with Vaccinia, or Cow-Pox, is used, and it is now generally believed that the virus of Variola and Vaccinia is one and the same, the human virus being weakened or attenuated by passage through the cow. Attenuation can be effected in a variety of ways:

(*a*) As in the above example, by passage of the virus through another species of animal.

(*b*) By desiccation of the virus. In the preventive treatment of Rabies inoculations are made with emulsions of the spinal cords of rabbits which have died from the disease, the cords being dried for a certain number of days over caustic soda.

(*c*) By cultivating the bacteria at an unduly high temperature. Pasteur obtained cultures of Anthrax of lessened virulence by twenty-four days' cultivation at 42° C. These cultures were used by him in immunizing cattle and sheep against this disease.

(*d*) By continued cultivation of the bacterium on ordinary media or on media containing antiseptics. Streptococci and pneumococci readily lose their virulence when artificially cultivated.

(3) By inoculation with dead bacteria. Suspensions of dead bacteria in normal salt solution are called **Vaccines,** and their

use has given efficient results in protecting people exposed to Plague, Cholera, and Typhoid Fever.

(4) By inoculation with an **Antitoxin.** This is an example of **passive** immunity in contrast to the preceding, which are examples of **active** immunity. In the latter the individual's cells and tissues manufacture an antidote to the infective agent; in the former protection is effected by the introduction into the body of the person exposed to infection of antibodies contained in the serum of an animal which has been actively immunized with dead or living virus or its toxins.

Children exposed to infection with Diphtheria are sometimes given prophylactic doses of antitoxin—*i.e.*, the serum of a horse which has been injected for some months with the toxins of the *B. diphtheriæ*.

Many theories have been advanced to explain the nature of active immunity, but up to the present none is entirely satisfactory. Before we deal with these theories, it is necessary to have some knowledge of the means by which bacteria produce their effects.

Occasionally masses of bacteria may mechanically obstruct capillaries, and in this way damage the cells supplied by the vessel, but the chief weapon of the invading bacterium is its capacity to produce **Toxins,** or poisons. In the case of certain bacteria—*e.g.*, *B. diphtheriæ*, *B. tetani*—these toxins diffuse outside the bodies of the bacteria, and are present in the medium in which the micro-organism is growing. Such toxins are said to be extracellular, and are present in the filtrate obtained from cultures. The majority of bacteria retain their toxins inside their bodies, and such intracellular or endotoxins only pass into the medium on the dissolution of the bacteria themselves.

Toxins have never been obtained in a pure state, so that their chemical composition is unknown, but it is probable that, although invariably associated with proteins, they are of a simpler constitution than the latter. One of the most characteristic properties of a toxin is its capacity to produce an antidote to itself (antitoxin) when injected into the body of a susceptible animal. Toxins exercise an effect on the various systems of the body—*e.g.*, nervous, circulatory, respiratory,

alimentary, and renal symptoms are common. Disturbance of the thermotaxic mechanism of the body is shown by the presence of fever or a subnormal temperature. The tissue cells react to the irritation produced by toxins in special ways. The phenomena of inflammation and granuloma formation are the result of the stimulus produced by a bacterium or other micro-organism. Some toxins are destroyed by comparatively low temperatures—*e.g.*, 65° C.—and in this respect resemble enzymes, whilst others are more heat resistant. Toxins are uncrystallizable, and in this they differ from **Ptomaines,** which are basic bodies of comparatively simple constitution found in decomposing protein matter—*e.g.*, cadaverin, cholin, etc. Toxins are dialyzable, and their molecules are smaller than those of antitoxins, since the latter, unlike the former, cannot be forced through filters covered with a thin film of gelatine.

Bacteria produce local and general effects in the body. In some cases, as in Diphtheria and Tetanus, they remain at the seat of inoculation, and the distal effects are due to the absorption of their toxins; in others the bacteria gain access to the lymph and blood streams, and are scattered over the body; but in most cases special regions bear the brunt of the attack. In all cases there is a fight between the cells of the body and the bacteria, and the termination of the disease depends on which side is victorious in the struggle.

The epidermis and the mucous membranes of the body act as barriers to the passage of bacteria into the tissues, but when these are forced the tissues have other inner lines of defence.

THE MECHANISM OF IMMUNITY.—The discovery by Metchnikoff that the white blood-corpuscles are capable of taking up and, by intracellular digestion, destroying bacteria, initiated a new epoch in the study of immunity. To this process the term **Phagocytosis** has been applied, and the intracellular enzyme has been called a cytase. The phagocytes, or white cells, are divided into two classes: the microphages or polymorphonuclear leucocytes of the blood, chiefly active in infection by cocci; and the macrophages, consisting of hyaline leucocytes, endothelial, and fixed connective-tissue cells, the principal defenders in protozoal and certain bacillary invasions. Whilst the French considered the cells the essential elements in

Immunity, the Germans laid particular stress on the bactericidal power of the plasma, lymph, and other humours of the body. It was discovered that the cell-free peritoneal fluid and blood-serum of an animal which had been inoculated with cultures of the *Vibrio choleræ* possessed the power of destroying living vibrios when brought into contact with them. Such serum also was found to cause the vibrios to gather into clumps, or to be agglutinated. Investigation showed that the agglutination of the bacteria and their dissolution was due to different components in the serum. The agglutination was due to a body termed an **Agglutinin,** which was not destroyed by a temperature of 55° C., whereas this temperature continued for a few minutes destroyed the bactericidal power, which, however, was recovered on the addition of a few drops of fresh normal serum. It has been clearly demonstrated that the destruction of bacteria, or bacteriolysis, which the serum of an animal immunized with the bacteria in question is capable of effecting, is due to the presence of two distinct substances in the serum, one, known as **Complement,** of an enzyme nature and heat labile, being present in all fresh sera; the other **Immune Body,** or **Amboceptor,** which is heat stable, being only found in immune serum.

Besides **Agglutinins** and **Bacteriolysins** there are present in immune serum substances known as **Opsonins,** which play a most important part in the defence of the body. Wright and Douglas showed that white blood-corpuscles phagocytozed bacteria suspended in normal saline solution to only a very slight extent, whereas bacteria that had been previously exposed to the action of fresh serum were rapidly ingested by the leucocytes. To the substance in the serum which combined with the bacteria and prepared them for phagocytosis these scientists gave the name Opsonin.

Opsonin is present in normal serum and is heat labile, being destroyed by a temperature of 60° C. in ten minutes; a similar body present in immune serum, and which is heat stable, is called a **Bacteriotropin** (Neufeld). It is probable that opsonins and bacteriotropins, like the bacteriolysins, contain several component parts, but their exact nature has not yet been definitely fixed. The result of Wright's work is to show that

in immunity both the cells and the body fluids are actively concerned in the process, and that by the determination of the opsonic index a means of gauging the resistant power of an individual is available.

The opsonic index is the ratio between the phagocytosis observed when bacteria are treated with two different sera, one, that of the observer, being supposed to be normal, the other, that of a person suspected to be infected by the bacteria in question. In carrying out the experiment, the leucocytes of the observer are employed. Suppose that on an average there were two bacteria present in each phagocyte where the observer's blood-serum was used and only one where the patient's was employed, then the opsonic index would be half the normal, or 0·5.

Ehrlich's Side-Chain Theory.—This theory attempts to offer an explanation of immunity which will bring the subject into line with other physiological phenomena. It is only against certain classes of substances that immunity can be developed—*e.g.*, toxins, enzymes, proteins, etc.—whereas others—*e.g.*, such poisons as strychnine on injection—lead to the production of no antibodies. Ehrlich holds that for the production of antibodies it is necessary that the immunizing substance, or **Antigen,** should enter into close chemical combination with a component part of a living cell, just as the different tissue cells obtain their nutrition from food substance dissolved in the blood. Ehrlich regards living protoplasm as composed of a central molecule, to which are attached side-chains of atom groups. These **Side-Chains, or Receptors,** have unsatisfied combining affinities, which enable them to join to the cell substances present in the blood. Some of the receptors simply unite with the nutrient or other material, whilst others in addition, by enzyme action, prepare the substance for assimilation by the cell proper.

Now, when the side-chains, or receptors, get detached and pass into the blood-stream, they constitute the various antibodies found in immune serum. According to this theory, the antibodies would be developed in those cells for which the antigen had a special affinity—*e.g.*, tetanus antitoxins in the nerve cells, etc. The theory, however, does not exclude the

PLATE IV.

FIG. 9.—Diagram of Receptors (after Ehrlich).

(*From* Beattie and Dickson's "General Pathology.")

A, *A'*, Receptors of the *first* order (uniceptors) with a single haptophore group.

Tox, *Tox'*, Toxin molecule, with a haptophore part (*a*) and a toxophore part (*b*); at *A'* the toxin is united to cell by its haptophore (*a*).

B, *B'*, Receptors of the *second* order with a single haptophore group (*c*), and a group with a ferment capacity, zymophore (*d*); *F* = molecules of nutrient material, protein matter, or bacterial bodies.

C, *C'*, Receptors of the *third* order (amboceptors) with two haptophore groups, one of which combines with *F*, and the other with the haptophore group of the *complement;* the complement has a haptophore and a zymotoxic group.

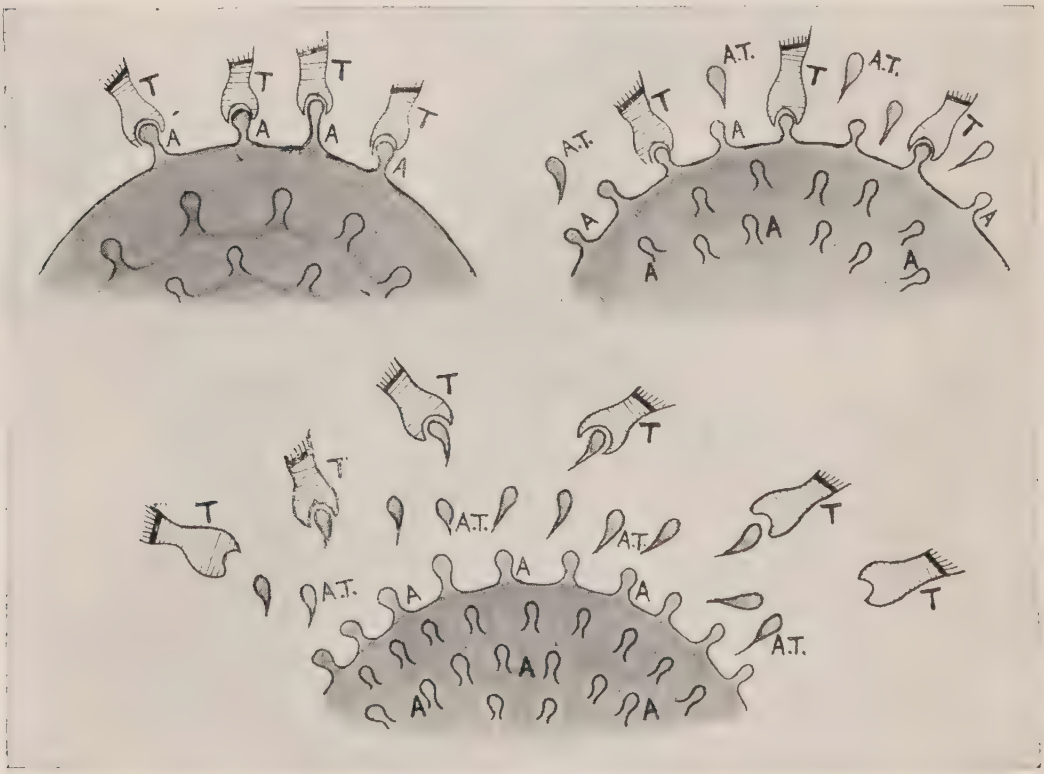

FIG. 10.—Diagram of Formation of Antitoxin (after Ehrlich).

(*From* Beattie and Dickson's "General Pathology.")

A = Uniceptors; *T* = Toxin molecules.

formation of these substances in other regions of the body. It is generally regarded that connective tissue and endothelial cells and the hæmopoietic system of the body—*e.g.*, bone-marrow, lymphatic glands—are the chief factories for the production of antibodies.

A toxin contains two groups of molecules—a combining or haptophorous group, and a functional or toxophorous group. When a toxin is introduced into the blood of a susceptible animal, the haptophorous group joins on to cell receptors, thereby leading to injury of the cells by the toxophorous molecule. If the injury is not extreme, the cell reacts and forms more receptors, and, in accordance with Weigert's law of supercompensation, the damage is more than replaced—more than the original number of receptors are formed, the surplus passing free into the blood.

According to this theory, the toxophorous part of the toxin molecule can damage the cells of the body only when the toxin has been joined to them by the haptophorous part. This view explains the natural immunity possessed by certain animals to poisons which are fearfully toxic to other species; in such cases the animal's cells have no receptors capable of combining with the toxin, which is thus incapable of producing its deadly effect—*e.g.*, Tetanus toxin has no effect on crocodiles.

Receptors are of three orders: (1) In the **first order** the receptor simply possesses a combining molecule. The antitoxin developed in the blood of animals which have been immunized with Diphtheria and Tetanus toxin consists of free receptors of the first order. Serum containing such antibodies is known as an antitoxin, and is used therapeutically, the union of the receptors contained in the serum on injection combining with, and in this way neutralizing, the toxins absorbed into the blood.

(2) In the **second order** the receptor possesses a functional as well as a combining group of molecules. To this class belong agglutinins and precipitins, which first of all combine with the agglutinogen and precipitinogen substance, and then by the action of the functional part of their molecule cause these substances to be agglutinated or precipitated.

(3) A receptor of the **third order** possesses two haptophorous groups, and is exemplified in the case of bacteriolysins, hæmo-

lysins, and cytolysins. Such receptors are known as amboceptors, or immune bodies. When a susceptible animal has been inoculated several times with bacteria, red blood-cells, or other cells, its serum is then capable of dissolving large quantities of such cells both *in vivo* and *in vitro*.

We have already seen that bacteriolysis requires the action of two distinct bodies—complement and immune body. The same applies with regard to the solution of red corpuscles and other cells—*i.e.*, to hæmolysis and cytolysis. The immune body possesses two haptophorous groups, the one capable of joining on to the bacterium or cell even at 0° C., the other uniting with complement at 20° to 37° C., and thus enabling the latter to exercise its solvent action.

Ehrlich's theory enables the mind to have a figurative representation of the chief facts of immunity, and although in this way false ideas may be conceived, still the theory offers an interpretation of the phenomena of immunity which harmonizes with our knowledge of cell nutrition, and the investigations along the lines marked out by the theory have led to most fruitful and practical results in the diagnosis and treatment of disease.

We shall here mention a few examples of the practical application of the facts of immunity in therapeutics and preventive medicine:

1. Vaccination with living attenuated viruses and with emulsions of dead bacteria, with a view (*a*) to the prevention of disease—*e.g.*, in Variola, Anthrax, Rabies, Plague, Cholera, Typhoid Fever; (*b*) to the cure of almost any infected condition —*e.g.*, the use of vaccines in infections with staphylococcus, streptococcus, pneumococcus, *B. coli*, *B. typhosus*, etc. Vaccine therapy is daily growing in importance.

2. The use of antitoxin obtained from horses immunized with the toxins of the Diphtheria bacillus in the treatment of Diphtheria in man.

3. The testing of blood-serum to ascertain if it contains specific agglutinins—*e.g.*, the Widal reaction in Typhoid Fever, Mediterranean Fever, Paratyphoid Fever, etc.

4. The use in forensic medicine of a serum containing precipitins for human serum to ascertain whether a blood-

stain is of human origin. The anaphylactic reaction is also used for the same purpose.

5. The use of serum of an animal immunized with a known bacillus to determine the identification of a doubtful one. The identification is also arrived at by a study of the action of the antibodies produced in an animal immunized with the unknown germ on a known bacillus.

6. Applying the properties of immune body and complement to ascertain whether a serum contains the former. A cardinal example is the Wassermann reaction in Syphilis.

At the present time chemotherapy under Ehrlich's guidance is making brilliant advances. The changes in spirillicidal power produced by changes in the radicles of certain organic substances, especially arsenical compounds of benzol, were chiefly observed, and led eventually to the discovery by Ehrlich and Hata of salvarsan (dioxy-diamido-arseno-benzol) as a cure for Syphilis.

The outstanding examples of successful chemotherapy have until quite recently been manifested in dealing with parasites belonging to the Protozoa—*e.g.*, quinine in Malaria; mercury and salvarsan in Syphilis, Yaws, and Relapsing Fever; emetine in Amœbic Dysentery; but Morgenroth's demonstration of the specific bactericidal action of ethyl-hydro-cuprein on pneumococci has raised the hope that eventually for each bacterium a chemical antidote will be found which will be able to destroy it without injuring the tissues of its host.

The progress already made in chemotherapy has brought to preventive medicine a means of controlling, if not of ultimately stamping out, that scourge of humanity—Syphilis. The fact that a person can now, if properly treated, be rendered non-infective in a few weeks shows that by the employment of adequate administrative measures this disease should become as rare as Smallpox.

Chemotherapy will probably be effective where, up to the present, the action of the immunizing mechanism has failed in dealing with such bacilli as the *B. typhosus*, *B. diphtheriæ*, *Vibrio choleræ*, etc., leading a more or less saprophytic existence in the bodies of "carriers." We see, therefore, that Therapeutics and Preventive Medicine cannot profitably be

dissociated—the treatment of the individual in such a way as to prevent him becoming a reservoir of pathogenic bacteria will, by diminishing the sources of infection, go far to eradicate from our midst many of the commoner infectious diseases.

Anaphylaxis.—This term was introduced by Richet in 1902 to indicate a condition (the reverse of prophylaxis) in which there was imparted to an animal by the injection of foreign protein a state of unusual susceptibility to this same protein when the inoculation was repeated. The primary injection is called the sensitizing dose, and the amount of protein required and contained in it may be almost infinitesimally small—*e.g.*, 0·00000005 gramme of egg-white is sufficient to produce the anaphylactic state in a guinea-pig. The symptoms and signs which arise on giving the second or exciting injection are known as those of anaphylactic shock, and are—(*a*) Paralysis of the arterioles, with marked fall of blood-pressure; (*b*)tonic contraction of plain muscle tissues, manifested by vomiting, urination, and diarrhœa, and by asphyxia, cyanosis, and emphysema due to a spasm of the bronchioles; (*c*) paresis or complete paralysis of voluntary muscles, followed by convulsions; (*d*) hyperæmia, inflammatory, or necrotic changes at the site of inoculation. Between the doses there must be an interval of eight to fourteen days. The symptoms, if severe, come on within ten minutes, and death may occur within half an hour. In many of the animals symptoms may not develop until three-quarters of an hour has elapsed, in which case they are milder, and are usually followed by recovery.

If the serum from a supersensitive animal be injected into a normal animal, the latter acquires the anaphylactic condition, and the supersensitive state is also transmitted by the female to her progeny.

The explanation of the phenomena of anaphylaxis is not yet definitely determined, but many believe that the symptoms are due to the action on the animal of products resulting from the lysis, or breaking-up, of the foreign protein. It is possible that as a result of the first injection a ferment is formed, which, after an interval, is present in the tissues in sufficient amount to rapidly split up the protein of the second injection into

toxic products, which are responsible for the consequences which follow.

Animals can be rendered anaphylactic by the injection of bacterial protein, and the view that many of the symptoms and signs of infectious diseases are instances of anaphylaxis has much to commend it. The period of incubation in many diseases is ten to fourteen days—an interval very similar to that required between the sensitizing and the exciting dose in anaphylaxis. Examples of natural anaphylaxis are Hay Fever and Asthmatic attacks induced by the breath of horses, cats, etc. Rosenau and Amoss showed that when the expired breath of human beings is condensed and the watery solution injected into guinea-pigs, the latter show anaphylactic symptoms when subsequently inoculated with human serum. Guinea-pigs can also acquire a sensitizing dose by inhaling the breath of dogs. It is probable that certain individuals can be sensitized by inhaling air vitiated by the expiration of other animals, notably horses. It is noteworthy that the majority of deaths from anaphylaxis following an inoculation with horse-serum have occurred in asthmatic subjects.

The reactions following inoculation of infected subjects with Tuberculin and Mallein are regarded by many as examples of anaphylaxis. The various idiosyncrasies with regard to certain articles of diet or certain drugs—the urticarial and other rashes and the vasomotor disturbances—find in the facts of anaphylaxis a possible explanation.

Anaphylaxis is not merely of academic interest, but assumes practical importance when the question of the use of horse-serum in the prevention and treatment of human disease arises. In giving antitoxin the following points should be noted:

(1) Do not inject an asthmatic patient unless the case is exceedingly severe. Where a state of hypersensitiveness to horse-serum is feared, inject a very small portion of the dose—*e.g.*, 0·1 c.c.—and if no untoward symptoms result, inject the remainder after an interval of three hours.

(2) If a series of injections are necessary in the treatment of a case, the second dose should be given within a week of the first.

(3) In view of the danger of anaphylaxis the routine inocula-

tion of "contacts" with prophylactic doses of Diphtheria antitoxin is not a measure that commends itself to many physicians at the present time.

It is safer to keep the children who have been exposed to infection under close observation, and to inoculate at once if symptoms of Diphtheria actually appear.

We may here remark that anaphylaxis must not be confounded with "**serum disease**"—a condition characterized by fever, rashes, œdema, pains in the joints, etc., which does not develop until the lapse of a week or ten days after inoculation with serum, whereas anaphylactic shock shows itself within an hour.

CHAPTER III

ANIMAL PARASITES

In our consideration of infective diseases we have seen that in many of these—particularly those occurring in warm climates—the infecting parasite belongs to the animal kingdom. Prominent examples of pathogenic **Protozoa** are the *Plasmodium malariæ,* the *Trypanosoma gambiense,* and the *Entamœba histolytica,* responsible as they are for the diseases Malaria, Sleeping Sickness, and Tropical Dysentery respectively.

Under certain circumstances man serves as a host for various species of **Insecta.** Apart from the discomfort and disgust produced by their presence, they also are responsible for the prevalence of certain diseases.

Animal parasites may be classified as **ectoparasites** and **endoparasites,** depending on whether they reside on the surface or in the interior of the body. Certain of the ectoparasites are permanently parasitic upon man—*e.g.*, lice—others only temporarily — *e.g.*, fleas, mosquitoes, bugs. The importance of ectoparasites as transmitters of disease has been emphasized by recent discoveries, especially in the field of tropical medicine.

Insects serve as hosts for pathogenic Vermes, Protozoa, Bacteria, and filterable Viruses. As regards man, insects are often called the intermediate hosts for these parasites; but according to strict zoological nomenclature, this term should only be applied to the host in which the asexual phase of the life-cycle of the parasite is passed, whilst the sexual cycle occurs in the definitive host. Biting insects may mechanically convey bacteria, and are then called "vectors of infection." In such instances as those of Malaria and Yellow Fever, where

the virus passes part of its life-cycle in the insect's body, the transmission is not merely mechanical, but biological.

The great majority of the ectoparasites of man belong to the Insecta class, but a few belong to the **Arachnida**—*e.g.*, ticks and mites. It was in 1893 that Theobald Smith showed that the infection of Texas or Red-Water Fever in cattle was conveyed by ticks, thereby establishing a new principle in preventive medicine. Ticks have an unsegmented body, with eight legs in the adult stage and six legs in the larval stage. The larva is developed from the egg, and after moulting becomes a nymph, which, like the adult, has eight legs; the nymph in turn moults, and becomes an adult tick. These developmental stages occur partly on the body of the host and partly in the field. The infective agent in Texas Fever is a protozoon, *Babesia bigemina*, contained in the red blood-corpuscles of the ox. Infected ticks can transmit the infection to their ova, and thus to their offspring. This accounts for the long persistence of the infection in certain pastures. Ticks convey the human diseases, Tick Fever and Rocky Mountain Spotted Fever.

Another acarine is the itch mite (*Sarcoptes scabiei*), which is the cause of a contagious skin affection in man. This parasite is minute, being about $\frac{1}{3}$ millimetre in length. The female, by burrowing in the skin, causes intense irritation. A frequent site of the burrows is the skin between the fingers. The Itch is liable to spread widely in barracks and other institutions, and for its prevention requires the disinfection of all clothing touched by the patient and the destruction of the parasites on his person by means of scrubbing with soap and water, followed by inunction with sulphur ointment.

Insecta.—An important order of this class is the Diptera, to which flies belong. Examples of biting flies are *Glossina palpalis*, *G. morsitans*, and *Stomoxys calcitrans*. The first two of these are concerned in the spread of Sleeping Sickness and Nagana, and the last may play a part in the dissemination of Infantile Paralysis. The house-fly (*Musca domestica*) does not bite, but can convey bacteria from filth to food; it is therefore an agent in the transmission of intestinal diseases such as Cholera, Dysentery, Diarrhœa, and Typhoid Fever.

PLATE V.

FIG. 11.—*Cimex lectularius*, or Common Bed-Bug. $\times 10$.

(*From* Beattie and Dickson's "General Pathology.")

FIG. 12.—*Pediculus capitis*, or Head-Louse. $\times 10$.

(*From* Beattie and Dickson's "General Pathology.")

Flies carry bacteria on their wings and feet, and in their crops and intestines. In feeding on solids, such as sugar, the fly ejects some fluid from the crop to dissolve its repast, and in this way contaminates the food with the bacteria contained in the crop, which were taken up when the animal had previously fed on garbage and excreta. Flies, like mosquitoes, pass in their development through four stages: (1) The egg or embryo; (2) the larva; (3) the pupa; and (4) the imago, or adult winged insect. Flies lay their eggs in horse manure, garbage, and organic refuse. The full development of the larvæ (maggot) occupies five days, when it becomes transformed into a pupa contained in a brown case—the puparium. The pupal stage also occupies about five days, so that on an average about ten days elapse between the egg and the imago. Knowledge of this fact shows the necessity of a weekly removal of manure, refuse, etc., so as not to allow time for the completion of this cycle of development.

In the chapter on tropical diseases attention is called to the part played by mosquitoes in the dissemination of disease. Fleas, lice, and bugs are degraded insects which have lost their wings. The eggs of fleas are laid in the fur or hair of their temporary hosts, and not being attached, fall to the ground, where further development occurs. *Pulex cheopis* in India and *Ceratophyllus fasciatus* in Europe are rat-fleas which also bite man, and so are concerned in the transmission of the Plague. The common flea is *Pulex irritans*. Fleas are temporary parasites on man, and in this resemble bugs, but differ from lice, which are permanent parasites. *Pediculus capitis* and the larger *Pediculus vestimenti* are probably both concerned in conveying Typhus Fever. Their ova are visible to the naked eye as white specks (" nits ") attached to the hair or clothing. The bed-bug, *Cimex lectularius*, is a flat, wingless insect about 5 millimetres in length, which lives in chinks in beds and walls, and usually attacks man during the night. Through the agency of bed-bugs and lice, Relapsing Fever is propagated.

Insecticides.—In the suppression of insects personal and municipal cleanliness are requisite. The removal of conditions facilitating the hatching of their ova is the first essential.

This is specially important in the campaign against mosquitoes and flies. Of chemical insecticides there are two of proven worth—sulphur and petroleum. For the destruction of insects in confined spaces fumes of sulphur dioxide—SO_2—are very effective. Petroleum, when added to water in the proportion of 1 ounce to every 15 square feet, by forming a film on the surface prevents mosquito larvæ obtaining air, and thus causes their suffocation. Petroleum, when sprayed in a flea-infected room, destroys these insects. It is also effective against lice and bugs. The treatment of a lousy person should be as follows: (1) The hair of the head should be soaked with a mixture of equal parts of petroleum and olive-oil, and then covered with a cloth. (2) The next day the room should be fumigated with burning sulphur, and all the bed-clothes should either be boiled or disinfected in a steam or hot-air disinfector. (3) The patient should then in a bath be thoroughly scrubbed from head to foot with soap and water and his clothes disinfected. A fine comb moistened with methylated spirit should be employed for removing the nits, and should be dipped from time to time in a 1 in 50 solution of carbolic acid. The process of head cleansing should be carried out on two or three occasions. Many sanitary authorities at their disinfecting stations provide the necessary apparatus and attendants for the cleansing of verminous persons.

Insect powders, usually containing pyrethrum, are useful, but very often are unable to reach the pests.

It is practically impossible to eradicate bugs from an old house where there are many chinks in the woodwork. The measures that are most often successful are fumigating with sulphur dioxide, injection of petroleum and saturated watery solutions of corrosive sublimate into all affected parts of the building.

The presence of dogs very often is the source of fleas in a house, and they and their kennels should be washed with soap and water and with a 5 per cent. solution of creolin. Petroleum may also be employed, but the danger of fire which its use entails must be carefully borne in mind.

Endoparasites.—In this section we shall consider the chief members of the Vermes class infecting man, treating the

subject from the point of view of the hygienist rather than from that of the zoologist.

Parasitic worms belong to two great classes—the **Platyhelminthes,** or flat-worms, and the **Nemathelminthes,** or round-worms. The flat-worms are ribbon or leaf-shaped solid bodies possessing no body cavity and no circulatory or respiratory apparatus, and even the alimentary canal is either absent or consists of a closed forked tube. The greater part of the body consists of the sexual apparatus, and as the worms are bisexual, testes and ovaries with their various ducts are both present. The round-worms are thread-like or cord-like in shape, often with tapering extremities. There is a well-developed alimentary canal with a mouth and anus, and surrounding the canal is a spacious body cavity. No specialized circulatory or respiratory systems exist, but for purposes of excretion there is a long tube running down either side of the worm, and opening on the surface by a common pore. The body wall is largely composed of muscle fibres, covered over by a thick cuticle. The worms may be bisexual or hermaphrodite; the females are usually twice as long as the males, and the tails of the latter are usually curled or expanded in an umbrella-shaped fashion—points which assist in the rapid recognition of the sex of a specimen.

Platyhelminthes are divided into the **Cestoda** and the **Trematoda.** To the Cestoda belong two families, the **Tæniidæ** and the **Dibothriocephalidæ,** the former including *Tœnia solium, T. saginata, T. echinococcus,* and the latter *Bothriocephalus latus.* The recognition of these parasites and a knowledge of their life-history is necessary in order that adequate preventive measures may be taken against infection with them. These worms for their continued existence require two hosts—one the intermediate host, the other the definitive host in which the sexual development occurs. In the case of *Tœnia solium* and *T. saginata* and *Bothriocephalus latus,* man is the definitive host, the intermediate hosts being, respectively, the pig, the ox, and the pike or other fish.

The adult worm in the case of the Cestoda consists of a head and neck (**scolex**), followed by a number of quadrilateral segments (**proglottides**). The head, which is about the size of

a pin-head, is provided with suckers, and in many cases with hooklets, which serve to attach the worm to the lining of the intestine. The proglottides are in the main occupied by the ovaries and testes and their adnexa, and from these the fertilized eggs are discharged in large numbers in the excreta. The ova are microscopic in size, and in the different genera have a characteristic appearance. When the ova are swallowed by the intermediate host, the embryos, termed Onchospheres, are set free in the intestines, and, by means of six spines with which one of their poles is provided, proceed to bore their way through the mucous membrane, and eventually reach the liver, lungs, muscles, etc., being probably transported by the blood-stream. On coming to rest in these situations, the embryo loses its spines, grows in size, becomes cystic through distension of its body with dropsical fluid. The cysts thus formed vary in size from that of a small pea to that of a child's head. The small cysts are termed **cysticerci,** and from the pole opposite to that on which the spines were situated, a scolex exactly similar to that of the adult worm develops, and projects into the interior of the sac. In the larger cysts, named **echinococcic,** the scolices are developed from brood-capsules, which are projections inwards of the inner or germinal layer of the sac. The outer layer consists of chitinous material arranged in concentric strata. The watery fluid contained in these echinococcic or hydatid cysts is clear, is free from albumin, and contains only 1·5 per cent. of solids, of which at least half consists of sodium chloride. The parasitic nature of a cyst containing such a fluid is diagnosed by the discovery in it of the characteristic hooklets derived from the scolices.

In the case of *Bothriocephalus latus*, no cyst development occurs; the embryo or plerocercoid elongates to form a minute worm with a head provided with two suckers.

Tænia solium is found in man's small intestine, infection being due to the eating of imperfectly cooked "measly" pork containing *Cysticerci cellulosæ*, the name given to the cysts found in the pig's muscles. The worm is often 3 metres in length, and consists of several hundreds of proglottides. The scolex has a terminal projection, or rostellum, arranged around which are four suckers and a double row of hooklets.

PLATE VI.

FIG. 13.—Scolex of *T. solium*, showing Hooklets and Suckers. × 24.

FIG. 14.—*T. echinococcus* (adult). × 15.

(*From* Beattie and Dickson's "General Pathology.")

FIG. 15.—*Ankylostoma duodenale*. × 7. Male is the smaller and shows expansion at its posterior extremity.

(*From* Beattie and Dickson's "General Pathology.")

FIG. 16.—Trichinella Embryos encysted in Human Muscle. × 40.

(*From* Beattie and Dickson's "General Pathology.")

The beef tapeworm, *Tænia saginata,* is more frequently met with in this country than the *T. solium,* from which it differs in being longer (6 metres), and in the fact that the scolex has no rostellum and no hooklets. The cystic stage of the worm (*Cysticercus bovis*) occurs in the flesh of cattle, causing "beef measles." To contract infection the beef must be very imperfectly cooked, or even raw, since a temperature of 48° C. readily kills the immature worm.

Bothriocephalus latus is the largest of the tapeworms found in the intestine of man, a length of 8 or 10 metres being not uncommon. The head is not globular, as in the case of the others, but is an elongated ovoid 2·5 millimetres in its long axis, and on two sides there is a groove or sucker. The pike, perch, or other fishes play the part of intermediate host, the ciliated embryo being absorbed from water. Infection with this worm is chiefly met with among the population residing on the shores of the Baltic. The parasite is able to survive the process of salting, pickling, and smoking employed in the curing of the fish.

The preventive measures to be taken in the case of the three Cestodes considered consist (1) in the adequate cooking of pork, meat, and fish; (2) the disposal of the fæces of infected individuals in such a way as to preclude the infection of the intermediate host.

In the case of *Tænia echinococcus,* the adult worm is found in the intestine of the dog, whilst the cystic stage may be passed in the body of a man, pig, or sheep. The adult worm is small, 5 millimetres being its length, and it consists of four segments, the last containing the genital organs, and being equal in size to the rest of the worm. The head has a rostellum, two rows of hooklets, and four suckers. When the ova are swallowed by the intermediate host, the embryos developed from them migrate from the intestine usually to the liver and lungs, and there form the echincoccic or hydatid cysts characteristic of infection with this parasite.

Man contracts infection through swallowing water or salad contaminated with the fæces of an infected dog, or through intimate association with such an animal. In parts of Australia and Iceland the disease is very prevalent. Prophylactic

measures are—(1) A supply of pure water and vegetables; (2) the prevention of dogs gaining access to offal in slaughter-yards or elsewhere, whereby they would acquire infection if the latter contained echinococcus cysts; (3) supplying dogs with only cooked meat; (4) the avoidance of the contamination of one's person with the secretions and excretions of dogs.

Trematoda.—In this class of flat-worms the individuals are unsegmented, often leaf-shaped, and possess a mouth and a pharynx which bifurcates into two blind, simple, or branched tubes, and have suckers on the ventral surface of their bodies. The majority are hermaphrodite, but in the **family Schistosomidæ,** which is the most important as regards human pathology, the sexes are separate. From the ovum is developed a ciliated embryo, the miracidium, which, entering the body of its intermediate host, passes through a series of metamorphoses, giving rise eventually to immature distoms—*cercariæ*—which, if swallowed by a definitive host, settle in various organs, and there develop into sexually mature worms. The two best-known **families** of this class are the **Fasciolidæ** and the **Schistosomidæ**; to the former belong the *Fasciola hepatica* and *Paragonimus westermanni,* and to the latter the *Bilharzia hœmatobia.*

The fluke, or *Fasciola hepatica,* is a common parasite of the bile-ducts of cattle and sheep, and on very rare occasions man may also serve as definitive host. A common water-snail—*Limnœa truncatula*—is the intermediate host, and from it the cercariæ emerge, and usually become encysted on grass, and in this state may readily be swallowed by sheep or cattle. In these animals the flukes invade the bile-ducts, causing a dilatation of the ducts and an increase of connective tissue, which leads to partial obstruction, ascites, and emaciation. In mild cases symptoms may be absent, but, where pronounced, the condition is termed "sheep rot." Flukes resemble minute soles, and measure about 2 or 3 centimetres by 1 centimetre.

A minute oval fluke, about 1 centimetre in length, is found as a parasite in the human bronchi in certain parts of Japan and China, causing hæmoptysis by its presence.

Bilharziasis is a diseased condition, the symptoms of which are due to the presence in the body of the *Bilharzia hœmatobia* (now termed *Schistosomum hœmatobium*) and its ova. The sexes

are separate, and the male worm measures 1 centimetre, whilst the female is twice this length, but much slenderer and more thread-like. The male worm is **C**-shaped, and a hollow canal—the gynæcophoric canal—runs from a ventrally placed sucker to the tail. The surface of its body is tuberculated. In the female worm a zigzag black line, representing the alimentary canal filled with blood, is a conspicuous object. The ova are large (0·08 by 0·03 millimetre) and are boat-shaped, the bow being projected into a sharp terminal spine; occasionally the spine is laterally placed. How the parasites enter the body is uncertain, but apparently the liver is the first organ in which they settle, since it is in this site that very young worms are found. From the liver the worms enter the branches of the portal vein, where conjugation occurs, and in the veins of the pelvis the females lay their eggs. The irritation caused by the presence of these ova in the bladder, kidneys, and rectum stimulates the growth of connective tissue, and ends in ulceration. In the rectum and colon a papillomatous condition of the mucous membrane may ensue, and a form of Bilharzial Dysentery result. Hæmaturia is the chief bladder symptom. The condition is diagnosed by the discovery of the characteristic ova. The disease is widely distributed in Africa, being specially common in Egypt and the Transvaal.

Preventive Measures.—Infection is probably derived from water, since the miracidium hatches out from the ovum when the urine or fæces are passed into water. This development does not occur if these excreta are passed into dry sand or earth, nor in the undiluted urine; hence measures should be taken to prevent water gaining access to the excreta. Some authorities believe that infection occurs by swallowing infected water, but the fact that the miracidia are killed in a few minutes by a solution of hydrochloric acid four times weaker than that present in the gastric juice, militates against this theory. Looss believes that the miracidia enter through the skin, and advances in support of this view the fact that the disease is unequally distributed among a population having the same water-supply, and that children in towns and children and adults in the country are more frequently attacked than adults in the town, the chief difference in the mode of life of

the two classes being apparently the more frequent opportunities of the bare feet and body of the former being brought into contact with infected soil or water.

Nemathelminthes.—In the following table the chief human parasitic worms of this Class are grouped:

Family Ascaridæ—*e.g.*, *Ascaris lumbricoides*, *Oxyuris vermicularis*.

Family Strongylidæ—*e.g.*, *Eustrongylus gigas*, *Ankylostoma duodenale*.

Family Trichotrachelidæ — *e.g.*, *Trichocephalus dispar*, *Trichina spiralis*.

Family Filaridæ—*e.g.*, *Filaria medinensis*, *F. sanguinis hominis*.

Ascaris lumbricoides has much the same appearance as the ordinary earth-worm. The female is 20 to 40 centimetres in length, whilst the male, the tail of which is strongly curved, is only 15 to 25 centimetres. The ova of the worm, like those of most of the Nemathelminthes, have a characteristic appearance, and their discovery in the fæces assists in the diagnosis in many of these infections.

Infection is direct, and is conveyed by drinking-water containing the ova. The ova require to remain in the soil a month before they are infective. During this time the embryo is developed. Fresh eggs if ingested are passed through the intestine without being hatched. The worms are found in the small intestine, but may wander into the stomach and crawl up the œsophagus and appear in the nose or mouth. Nervous symptoms are often present. The thread-worm, or *Oxyuris vermicularis*, is often present in the rectum, and even in the whole extent of the colon of children. The length of the female is 9 to 12 millimetres, that of the male 3 to 5 millimetres. The worm causes irritation and scratching of the perinæum, and the child then often puts his soiled fingers containing ova into his mouth, and in this way a vicious circle is established and infection is kept up. The ova are probably conveyed by water and fruit, and infection is direct, no intermediate host being required.

Characteristic features of the **Strongylidæ** are the expanded

copulatory bursa in which the tail of the male ends, and the six papillæ in the mouth, which is also often provided with chitinous teeth and hooklets.

Eustrongylus gigas resembles a large *Ascaris lumbricoides*, is blood-red in colour, and is usually found in the pelvis of the kidney. *Ankylostoma duodenale* is one of the most widely distributed parasitic worms, and is recognized as the cause of a profound and often fatal Anæmia in a certain percentage of those harbouring it. The worms are found in large numbers in the jejunum, less often in the duodenum. By means of four hooks and two teeth with which their mouths are provided, they attach themselves to the mucous membrane. The length of the male is about 9 millimetres, and that of the female 15 millimetres. The ova are passed in the fæces, and in soil of suitable humidity and temperature develop an embryo, which moults twice, and can then, if brought into contact with the human skin, pass through the hair-follicles into the underlying lymphatics and bloodvessels, and in these pass to the lungs. In the lungs the embryos pass into the air-sacs, where they undergo their third ecdysis, after which they wriggle up the trachea and down the œsophagus to the jejunum, where their further development occurs. Besides the presence of the worm, other factors apparently are required in order that symptoms may arise, since Boycott found among Cornish tin-miners only 5 per cent. of those harbouring the worm suffered ill-health in consequence.

The soil of Egypt and of certain mines favours infection, and the frequent occurrence among workers in Egypt and among miners has caused the disease often to be termed **Egyptian Chlorosis,** or **Miner's Anæmia**, and to the dermatitis caused by the entrance of the parasite through the skin the name **Cooley Itch** is often given. The eggs themselves are not infective, but only when they have been hatched into the larvæ. Below a temperature of 13° C. the eggs will not hatch, and for optimum development a temperature of 25° C. and upwards is required; but a temperature of 40° C. kills the larva if continued for twenty-four hours.

The temperature of English coal-mines is too low for the development of the larva, but Cornish tin-miners suffer.

Preventive measures consist (1) in the discovery of all carriers of ova, their radical treatment with thymol or other vermicide; (2) the prevention of the pollution of the soil of mines, etc., by infected stools. In all mines proper sanitary conveniences should be available, and strict regulations made and enforced with regard to their use.

Trichotrachelidæ.—Well-known examples of this family are the *Trichocephalus trichiurus*, or "whip-worm," and *Trichina spiralis.* The neck of the worm is long and slender, and at its junction with the stouter body is situated in the female the genital pore. The whip-worm is often found attached to the mucous membrane of the cæcum, but its presence causes few or no symptoms. A much more important parasite is the *T. spiralis,* the embryos of which become encysted in the voluntary muscles of the rat, pig, and man. When man consumes pork containing living embryos—*Trichinellæ spirales*—the latter are set free, and in his small intestine attain adult size, the males measuring 1 to 5 millimetres in length, and the females, after copulation, 3 millimetres. The females discharge the young embryos into lymph vessels of the intestine, and from these the voluntary muscles are reached in which the trichinellæ settle. The muscles attacked in order of frequency are the diaphragm, the intercostal muscles, muscles of the neck and eyes, and limb muscles. Infection is characterized by fever, gastro-intestinal disturbance, swelling and tenderness of the muscles, prostration. In many particulars the disease produced—**Trichinosis**—resembles Typhoid Fever and Beri-Beri. The trichinellæ, about 7 millimetres in length, become curled up inside little oval cysts (7 millimetres in their long axes), which are just visible as white specks to the naked eye. The trichinellæ are exceedingly resistant to unfavourable surroundings; they have been found alive in putrid meat at the end of one hundred days, and in pork they can bear exposure to temperature of 70° C., or even 80° C.

Apparently infection among rats acquired in abattoirs is kept up by the cannibalism that exists among the species, and from the rat the pig acquires the infection, which is passed on to man.

Preventive measures consist in—(1) Killing of rats in the

neighbourhood of slaughter-houses and piggeries; (2) the thorough cooking of ham and bacon, and also of sausages, since the trichinellæ encyst not only in the muscles, but also in the panniculus adiposus.

The **Filaridæ** are long thread-like worms of uniform diameter throughout. *Filaria medinensis* is found infecting man in Asia, South America, and Africa; and from the frequency of the occurrence in the West Coast of Africa, it has been called the Guinea Worm. The adult female worm is about 1·5 millimetres in diameter, and 500 to 800 millimetres in length, and is usually found in the subcutaneous tissue near the ankle. The presence of the worm produces a boil-like swelling, which eventually ulcerates, and from this ulcer part of the body of the worm protrudes. When the foot of its host is placed in water the female discharges a milky fluid containing embryos into it. In the water the embryos pass into the body of a copepod of the genus Cyclops. In the body of this crustacean they remain active for two or three weeks, and then become quiescent. If the Cyclops is placed in a fluid containing 0·2 per cent. HCl, such as the gastric juice, it is killed, and the embryo Filaria is set free. Considerable gaps exist in our knowledge of the further stages in the development of the worms, but after nine months or so in the human body the female worm appears at the surface of the body in a position to discharge her embryo into water.

The preventive measures are—(1) Destruction of the worms in the subcutaneous tissues by injection of vermicides; (2) the securing of a pure water-supply—especially the use of deep-well water.

There are several species of *Filaria sanguinis hominis*, distinguished by the time at which their larval forms appear in the blood, whether constantly or only at night or day time. The adult forms, corresponding to the *Microfilaria nocturna*, are respectively *Filaria loa*, *F. perstans*, and *F. bancrofti*. The adult worms are from 10 centimetres in length, and about the thickness of linen thread. The adult worms are found in the lymphatic system of the hosts, and into the lymph which passes into the blood the female discharges the young larval forms, still ensheathed with the remains of the vitelline mem-

brane. These larval forms are about 0·2 millimetre in length, and about 8 μ in diameter, so that they can pass through the blood-capillaries. The lashing movements caused by these microfilariæ is readily observed in a drop of blood under the low power of the microscope. These microfilariæ, when taken up in blood into the stomach of various mosquitoes —*Culex fatigans, Anopheles rossi, Stegomyia calopus*—rupture their sheaths, burrow their way into the thoracic muscles, attain a length of 1·5 millimetres, and reach the labium of the insects, ready to pass into a new host when the insect bites.

In man the thoracic duct may be occluded by the worms or by the inflammatory change produced by their presence leading to lymphatic varices, and to a hyperplasia of the connective tissue of the region bathed with the lymph. Chyluria may follow from the rupture of one of the distended lymph vessels in the bladder wall and the escape of lymph containing microfilariæ in the urine. To the enormous enlargement of the limbs and scrotum that occur the term **elephantiasis arabum** has been given.

CHAPTER IV

HEREDITY AND EUGENICS

WITH the establishment of the germ theory of disease there was a tendency to lay too much stress on the poisoning and mutilating action of the infecting parasite, and to overlook or consider of minor importance the powers of resistance of the tissues of the individual. The fact that the seed can only develop in a suitable soil was to some extent neglected, whereas the older physicians laid particular stress on the patient's constitution. At the present time the pendulum of medical opinion is swinging back towards the old position, as is shown especially by the progress of Eugenics.

The late Sir Francis Galton, the founder of the **Eugenics** movement, defined this new branch of science as "the study of agencies under social control that may improve or impair the racial qualities of future generations either physically or mentally." From this definition it is evident that it includes not only the study of the effects of heredity, but also of environment; but since leading Eugenists like Karl Pearson claim that Nature has from five to ten times more influence on health than nurture, Eugenics is chiefly, though not exclusively, concerned with the study of heredity and its bearing on social problems.

The object of the Eugenist and the Hygienist is the same—*Mens sana in corpore sano.* The difference between them consists in the fact that the Eugenist aims at this by improving the stock, the Hygienist by bettering the environment. At the same time, it must be remembered that an improvement of the environment will also, to a certain extent, favour the production of healthy, or at any rate help to prevent the production of diseased, children. For instance, no one will deny that the child born of parents who live in hygienic surroundings

and who are properly fed will have a distinct advantage over the child of parents who are underfed or who are poisoned with alcohol, lead, or the virus of syphilis, and whose surroundings are insanitary. Eugenics and Hygiene are both concerned in the prevention of those diseases which are usually termed "congenital." According to the teaching of Weismann and his school, acquired characters are not transmissible. The only conditions which are capable of being inherited are those which have told upon and modified the nuclear material of the germ cells of either parent prior to or at the moment of fusion. It is at the moment of fusion that the new individual begins its existence. Any influence acting upon and modifying it after this moment is something acquired by what is already a separate entity: it is not inherited.

Acquired Conditions may be (*a*) ante-natal, (*b*) parturient, (*c*) post-natal. The study of ante-natal and parturient conditions comes within the province of Eugenics as well as of Hygiene. Both should co-operate in the prevention of congenital Syphilis and Ophthalmia Neonatorum.

The study of heredity belongs to the science of Genetics, and Eugenics is applied Genetics and something more. Genetics is a pure science which is working to bring law and order into the inchoate mass of the facts of heredity; whilst Eugenics strives to lead man to use his conscience as well as his intellect in dealing with his knowledge. That it is the duty of the individual to consider the claims of those who shall come after is the teaching of Eugenics. Genetics has shown that not only the bodily, but also the emotional and mental characters of a man depend on his forbears; and Eugenics appeals to the fit, the useful, and the sane to contribute to the next generation as large as or a larger proportion than has been done by their class in the past, and at the same time to discourage the unfit and degenerate from reproducing their kind.

Laws of Inheritance.—Galton, from his study of the inheritance of coat colour in the breeding of Basset hounds, tentatively formulated what he called the **ancestral law,** according to which, in the making up of any one individual, the average contribution of each parent is one-quarter, of each grandparent $\frac{1}{16}$, and so on. Karl Pearson, the chief exponent

of the **biometric method** of studying inheritance, makes use of a coefficient of correlation which measures the ratio of the number of absolutely associated contributary causes to the total number of such causes. "The theory of correlation is a calculus by which we measure the ratio of the common causal to the non-common contributory factors in two variable quantities. If we measure a character in father and son, these resemble each other in part because they are due to common causes—the germ plasm of the paternal stock or the hereditary factors; they differ because they are due to in part independent causes. Correlation measures the degree in which any pair of relatives resemble each other. Again, if we take the character in any individual and any phase of his environment, we can, by aid of the calculus of correlation, determine to what extent that character is associated or independent of the special phase of environment. It is thus that we are now able by a single number lying between 0 and 1 to express the intensity of causal relationship between any two variable quantities. The degree of resemblance between parent and offspring lies between 0·4 and 0·5; between offspring and grandparent, between 0·2 and 0·3; and between any grade of ancestor and the offspring the resemblance diminishes in geometrical progression, the factor of reduction lying between 0·5 and 0·6" (Pearson).

New light was thrown on the problem of heredity by the work of **Mendel,** Abbot of Brünn, which, although published in 1865, has obtained due recognition only in recent years. Mendel's experiments with the tall and dwarf varieties of the common eating pea are classical. These varieties, when self-fertilized, bred true, and when crossed, the resulting seeds gave rise only to tall forms. "When self-fertilized seeds from these plants were sown the following year, one-quarter proved to be dwarf plants, which once more bred perfectly true among themselves, and three-quarters were tall plants. But these tall plants, when their seed was sown, proved to be of two sorts; about one-third of them (one-quarter of the original number) gave rise only to tall plants, representing a pure type, whilst the remaining two-thirds once more produced offspring mixed in the proportion of three-quarters tall and one-quarter dwarf."

Thus certain qualities—for instance, tallness in the case of the pea—if present at all, manifest themselves in the outward appearance of the offspring (**dominant qualities**), and other qualities (**recessive qualities**) such as dwarfness may be transmitted from the germ cells of the parent to those of the child, and will only become outwardly apparent in certain circumstances. Such a condition occurs when both parents possess the same recessive character. Since few families are absolutely free from taint, and since this taint, if dominant, is liable to be transmitted to their offspring in an aggravated form, and if hidden or recessive is especially liable to come to the surface when both parents possess it, marriages between cousins and between persons having a neurotic and phthisical history are to be discountenanced.

The work of Mendel indicates that each parent contributes to the child a large number of unit characters, and that these as a rule do not blend, but remain separate and distinct (**segregation of unit characters**). We have already seen that these characters may be dominant or recessive. Now, although the child inherits and eventually possesses these unit characters, the latter are not transmitted as such in the germ cells. The germ cells possess a **determiner**—a something the nature of which is not understood—which determines the development of the unit characters. In the case of pigmentation the pigment is not preformed in the cells, but a force is transmitted which at a certain stage of development excites metabolism in such a way that pigment is produced.

Recent research has shown that a number of human characters and diseases are inherited along Mendelian lines. In the case of eye-colour, brown is dominant and blue recessive. Blue-eyed parents always have blue-eyed children. Certain abnormal conditions—*e.g.*, colour-blindness, night-blindness, brachydactyly—appear to act as dominants, whilst deaf-mutism is recessive.

Inherited Diseases.—We find that the list of diseases that are truly inherited, unaltered in type, is a comparatively small one. In such a list appear some rare forms of nerve disease—Hæmophilia, Daltonism, Albinism, Myopia, and Ichthyosis. These diseases also exemplify what is known as sex-limited

inheritance. The trait appears only in the males of the family, but is transmitted by the females who appear to be normal. The explanation of the phenomenon is the absence of a special determiner from the male sex chromosome.

In the majority of cases heredity affects the individual by giving him a constitution which may render him specially susceptible to infection with certain micro-organisms—*e.g.*, the tubercle bacillus—or to such disorders of metabolism as Obesity, Diabetes, Gout, and Chronic Rheumatism. But it is undoubtedly in the nervous system that we see most clearly the influence of heredity in the production of disease. Insanity, Epilepsy, Hysteria, and the various neuroses exemplify the inheritance of an unstable nervous system. Insanity may, and generally does, take different forms in different members of the same family. But that a hereditary disposition is the most important factor in its production few will dispute.

Extraneous causes—*e.g.*, worry, overwork, sorrow, alcoholism, etc.—may be, and often are, the exciting cause of the breakdown, but the cardinal fact is the neuropathic taint.

Dr. Mott, with the extensive material at his disposal in the London County asylums, has shown the importance of heredity to insanity. Of the 20,000 persons in these asylums, one in every ten is known to have had a near relative in one or other of them. Mott has shown: (1) That certain types of insanity are transmitted with greater frequency than others. Such examples of similar heredity are Periodic Insanity, Delusional Insanity, and Epilepsy; (2) that a mother transmits Insanity and Epilepsy with much greater frequency than a father, and the transmission is especially to the daughters. In the same paper Mott called attention to one of Nature's ways of terminating the perpetuation of the unsound elements of the stock. This is that condition known as "anticipation" or "ante-dating," whereby the offspring suffer at a much earlier age than the parent, and thus have less opportunities of reproducing their kind. More than half of the insane offspring of insane parents have the first attack in the period of adolescence.

When it is realized that on an average 1 in every 200 of the population of the British Isles is insane and 1 in every 200

feeble-minded, it is no wonder that the Eugenics Education Society is endeavouring to grapple with the question of the control of the feeble-minded. By "mentally defective or feeble-minded" is meant those who, by reason of mental defect, are incapable of receiving proper benefit from instruction in the ordinary public elementary school, but are not incapable by reason of such defect of receiving benefit in special classes or schools.

If the community at its expense undertakes the provision of suitable schools and institutions for the care of the feeble-minded, it is not unreasonable to expect that such people should be restrained from transmitting their inherent weakness to future generations.

Eugenists recognize that their efforts must not inflict unnecessary pain and suffering on those who are at present feeble-minded, even although their object is to prevent the transmission of the defect—the happiness of the born must not be sacrificed for the sake of the unborn.

The decline of the birth-rate in the various civilized countries of the world has become so marked that it has occupied the attention of politicians and publicists. The unfortunate circumstance about the decline is that it is due to the relative infertility of the most valuable stocks in the race, and the efforts that are being made to diminish infantile mortality tend still further to increase the number of the improvident relative to the number of the provident in the community.

In the ruder stages of man's development, where natural selection had full play, the weakest went to the wall, and the race benefited. To-day, by our social legislation, we are annulling the effects of a selective death-rate, and our only hope of salvation lies in a selective birth-rate.

At the present time the laws governing heredity are not sufficiently well understood to enable a right decision to be come to in many cases as to who are the fit and who the unfit, since it is well known that associated with insanity there is often the most brilliant genius. Still, I think it will be admitted that the habitual criminal, the professional tramp, the tuberculous, the insane, and the mentally feeble, are among the unfit.

In creating a sound public opinion on the importance of heredity in the prevention of disease, Eugenics is playing a leading rôle. Part of its programme—and probably the most important and practical item—includes the instruction of adolescents with regard to the physiology of reproduction and the blighting effects of venereal diseases. In the case of nervous disorders, especially feeble-mindedness, the segregation of the afflicted, both in their own interests and that of the community, is being attempted, and should eventually limit the multiplication of the unfit. In the fight against communicable diseases the resources of preventive medicine—isolation, disinfection, immunization, chemotherapy, improved housing and nutrition—will probably be successful, without any attempt being made to produce a race naturally immune. It would be no advantage to our nation to-day if two or three centuries ago our ancestors had acquired an immunity to Plague, Cholera, and Leprosy. These diseases have disappeared from our islands, and if introduced would by our present knowledge be prevented from spreading. Perhaps Tuberculosis may be an exception to the above generalization, and certainly a tuberculous family should be avoided when marriage is contemplated; still, we may recall how close is the relationship between Tuberculosis and Leprosy, and hope that the present crusade against the white plague may lead to its extinction in this country.

CHAPTER V

AIR

For the vital activity of higher animals and plants air is absolutely indispensable. Without food a man can live a few weeks, without water a few days, but in the absence of air he dies in three minutes. It is therefore necessary to have some knowledge of the chemical and physical properties of air, as well as of the organic and inorganic impurities that may be added to it.

Pure dry air on an average contains by volume 20·96 per cent. of oxygen, 78 of nitrogen, 1 part of argon, minute traces of the rare gases helium, krypton, neon, and zenon, together with 0·03 to 0·04 per cent. of carbonic acid gas. These gases are not chemically united with each other, but form a simple mixture. The amount of aqueous vapour present is very variable, but often reaches 1 per cent. Traces of ozone and hydrogen peroxide can be detected in the pure air of the country and sea, and in towns traces of ammonia, nitrous and nitric acids, sulphuretted hydrogen, and sulphurous acid may be found, especially in the neighbourhood of chemical works.

Nitrogen is a very inert substance, and, as in the free state it plays little or no part in the economy of plant and animal, its percentage in the atmosphere is very constant. The only exception to this statement, so far as is known, is the remarkable fact that the bacteria contained in the root nodules of the order Leguminosæ can from the nitrogen of the air synthesize compounds which supply the tissues of the plant with nitrogen. On the other hand, oxygen is being continually consumed in the respiration of animals and plants, and carbonic acid gas formed as a product. Animals cannot utilize carbonic acid gas, and, indeed, when present in high concentration, this gas acts on them as a narcotic poison, whereas green

plants are able, by means of the chlorophyll they possess, to assimilate the carbon and evolve the oxygen contained in the gas.

Again, in the process of combustion, fermentation, and putrefaction, oxygen is consumed, and carbonic acid gas evolved. It is a remarkable fact that the amount of oxygen and carbonic acid gas in the atmosphere remains fairly constant. Any tendency to a local surplus of carbonic acid gas or deficit of oxygen is prevented by the process of diffusion and by the action of wind and rain and vegetation.

The atmosphere probably extends upwards from the earth's surface a distance of forty miles, and it also penetrates into the pores and crevices of soil to a considerable depth. Soil air is characterized by its richness in carbonic acid gas resulting from the chemical and fermentative changes proceeding in the earth. The air of caves and wells may be so heavily laden with carbonic acid gas as to be irrespirable.

Air is a simple mixture of gases, and has the physical properties of gases in general. Thus: (1) It possesses weight and exercises pressure. At the sea-level this pressure will support a column of mercury 29·9 inches, or 760 millimetres, in height. This fact may be stated in another way by saying that the pressure of the atmosphere is fourteen pounds to the square inch, and that the surface of the body of an adult is subjected to a pressure of 14 tons. This pressure is unnoticed, since it is exercised in every direction, and since our bodies are adapted to it, just as the deep-sea animals are so constructed that they can withstand the pressure exerted by the supernatant water and air. (2) On change of pressure or temperature, air expands or contracts. According to Boyle's law, when the temperature remains constant, the volume is inversely proportional to the pressure. By means of enormous pressure exercised at an extremely low temperature, air passes from the gaseous into the liquid state. When air is heated it expands, and the amount of expansion follows the law of Charles; the volume of a given weight of air at a constant pressure is proportional to its absolute temperature. The increase of the unit of volume for one degree of temperature is called the "coefficient of ex-

pansion," and is the same for air as for all gases, and is $\frac{1}{273}$ for each degree Centigrade. (3) A process of diffusion is continually taking place among the constituent gases of the atmosphere, and between volumes of cold and heated air. According to Graham's law, the rate of diffusion is inversely as the square roots of the densities of the gases concerned.

These properties of air explain many of the phenomena of meteorology, and are the underlying principles concerned in heating and ventilation.

CLIMATOLOGY AND METEOROLOGY.

The **climate** of a country—by this term we understand the character of the weather as regards such meteorological conditions as heat and cold, humidity and dryness, alternations of seasons, etc.—has a most important influence on the health of its inhabitants. The natives of the different parts of the globe in the course of many generations have become adapted to the peculiar climatic conditions prevailing and to the diseases associated with these conditions, whereas the new-comer generally suffers severely in health. The progress of tropical medicine has shown that under favourable sanitary conditions, and by the practical application of the knowledge recently obtained regarding the etiology of the chief diseases of the tropics, Europeans during short service in these regions may be as healthy as at home. It is not so much the meteorological conditions themselves that affect health as the presence of certain pathogenic animal and vegetable parasites and their insect hosts depending upon these physical conditions.

The climate of a region is in the main determined by the following: (1) Distance from the Equator; (2) height above sea-level; (3) distance from the sea; (4) prevailing winds.

In the classification of climates latitude is the chief basis, but the other factors already mentioned, as well as the influence of warm and cold sea currents, must be considered. As regards their influence on the health of man, climates may be classed as warm, temperate, and cold. The warm are further subdivided into equatorial, tropical, and subtropical. The mean annual temperature of the equatorial is from 80° to 84° F., and the rain-

fall is rarely less than 40 inches annually. Common diseases of warm climates are Sunstroke, Yellow Fever, Malaria, Dengue, Dysentery, Liver Abscess, Smallpox, whilst Measles and Scarlet Fever are rare.

In the temperate climates there are four seasons, and not, as in the tropical, two—wet and dry. The mean temperature is 60° F., but variations are frequent and marked. Pneumonia and other affections of the air passages—Rheumatism, Measles, Scarlet Fever, Diphtheria, Whooping-Cough, and Influenza, are the prevailing diseases. In both warm and temperate climates Tuberculosis claims many victims.

In the cold climates of the Arctic and Antarctic regions the mean temperature is 17° F., the winter being long and dark, and summer lasting only a few weeks. Sojourners in these zones frequently suffer from Scurvy and affections of the eye.

Tropical and temperate climates are further usually subdivided into continental, insular, and mountainous. The presence of water with its low specific heat protects islands and places on the coast against the extremes of heat and cold which occur in continental places. The atmosphere is moister and rainfall greater than in inland districts. In mountainous regions the air is more rarefied and the barometric pressure low, the sky is clear, and terrestrial radiation and cold marked at night, but masked by the bright sunshine during the day.

Along with such purely meteorological conditions as amount of sunlight, temperature, humidity and movement of the air, and atmospheric pressure, the condition of the water and the soil, and especially the presence or absence of insect carriers of disease, must be taken into consideration as factors affecting the healthiness of a climate.

Sunlight.—Sunlight acts directly and indirectly on the health of man. On the individual the heat and brightness of moderately intense sunlight has a cheering and invigorating effect, and on his environment it acts as a great purifying agent. The actinic rays possess marked germicidal properties.

Exposure of the imperfectly protected head and neck to the direct rays of the sun, especially in tropical lands, may cause Sunstroke—a condition accompanied by a high body temperature, and unconsciousness, and which may terminate fatally

through paralysis of the cardiac and respiratory centres. It results from the thermotaxic mechanism of the body becoming deranged and perspiration checked, so that heat loss is interfered with; and in the case of men producing heat by active exertion, there is attained a condition of hyperthermia and its attendant symptoms. The preventive measures are the protection of the head and spine, and the performance of active exertion before the sun attains its strength.

The duration and intensity of sunshine can be recorded by such an instrument as that of Campbell-Stokes, in which the rays focussed by a glass sphere on a curved sheet of paper burn a track along the course of the latter.

Temperature.—The effects of the temperature of the air on the body are influenced not only by the degree of heat registered, but also by the amount of humidity and the rate of movement of the air. A stagnant moist heated air by preventing heat loss, and a cold wind by unduly promoting this result, are liable to disturb the health. In this country a temperature of 60° F. is the most agreeable, but the sudden drops which often occur predispose to catarrhal affections, especially of the air passages. Undoubtedly temperature of the air is one of the chief factors in the explanation of the seasonal prevalence of certain diseases. The human body, and especially that of the inhabitant of the temperate regions, is able to adapt itself to the most extreme degrees of heat or cold. When the European goes to the tropics, an elevation of the body temperature of about 0·8° F. occurs at first, but after a short residence the old normal is again maintained.

The effect of the tropical heat is to diminish the rate of respiration from 16 to 12, and as this is accompanied by diminished cardiac action and by a lowered percentage of CO_2 in the expired air, the value of the respiratory act in the tropics is below that of temperate climates. On the other hand, the action of the liver and of the kidneys is probably increased, although the amount of water in the urine is diminished owing to the more extensive loss by the skin. The increased heat may cause hyperæmia of the skin and an irritated condition known as "prickly heat." Excessive heat has an exhausting effect on the nervous system, and in some cases this may

be so marked that a condition of collapse or heat stroke is produced.

The invigorating effect of a keen, cold, still air is familiar to all. Extreme cold produces contraction of the arterioles of peripheral parts, bringing about arrest of metabolism, and, finally, frost-bite or gangrene. When the exposure is prolonged, sensibility becomes lowered, and from an overpowering feeling of languor the individual passes into a state of sleep and coma which finally ends in death.

In collecting meteorological data maximum and minimum thermometers are extensively used. In Negretti's maximum instrument there is a constriction at the junction of the bulb with the column which allows the mercury to pass over it on expansion, but which prevents its return into the bulb on contraction. In Phillip's instrument a portion of the mercury column detached from the rest by a bubble of air serves to indicate the maximum temperature attained. A special form of this instrument with a blackened bulb enclosed in a glass sheath, from which the air has been exhausted, is used for recording the maximum temperature attained when exposed to the direct rays of the sun. A minimum thermometer (Rutherford's) is filled with spirit, and in the index column there is a little metal rod which is drawn back by capillarity on the contraction of the spirit, but as the latter, on expansion, flows over it, the situation of the distal end of the rod indicates the lowest temperature reached. A form of this instrument, called a radiation minimum thermometer, is placed 4 inches above the ground, and is employed to measure the degree of radiation.

In Six's instrument there is a **U**-shaped bend filled with mercury, and above the mercury each column contains spirit, but one ends in a bulb filled with spirit, the other in a small air chamber. By means of this instrument both maximum and minimum readings can be taken. Resting on the mercury in each limb there is a small metal index. On a rise of temperature the spirit in the bulb expands, and the mercury in its limb is depressed, and a corresponding elevation of the mercury and index in the other limb occurs, so that the latter indicates the maximum temperature attained. On a fall of temperature,

the spirit in the bulb contracts, and the mercury and index in the corresponding column rise, and so the index in this limb records minimum temperatures.

Thermometers for recording temperature in the shade are placed 4 feet from the ground in a square box (Stevenson's), the sides of which are louvred.

Humidity.—An amount of moisture, corresponding to 70 to 75 per cent. of that required to cause saturation, renders the air most agreeable. When the air is deficient in moisture, it is apt to cause irritation of the air passages, and, on the other hand, excess causes discomfort through disturbance of the heat-regulating mechanism of the body.

In cotton-weaving sheds a humid atmosphere is necessary, but in the interests of the health of the operatives there is prescribed by statute for various temperatures various maximum amounts of moisture. In considering the ventilation of buildings, and especially of schools and factories, a determination of the relative humidity of the air—which is that proportion of the total possible amount of aqueous vapour which the atmosphere at a given temperature actually holds—is important. It is necessary first of all to determine the temperature at which the amount of moisture actually present in the air causes saturation —*i.e.*, the dew-point. By means of such instruments as Daniell's and Dines' **hygrometers**, the dew-point can be found directly, but for public health purposes the wet and dry bulb hygrometer is universally used. This instrument consists of two thermometers supported on a stand. The wet-bulb is surrounded with muslin, which is kept moist by distilled water passing up it by capillarity from a little beaker. Evaporation of the water causes a lowering of the temperature of the wet-bulb below that of the dry one, and, of course, the greater the drying power of the air the greater is the difference between the two. When the air is completely saturated, the wet and dry bulbs record the same temperature. Knowing the readings of the wet and dry bulb by means of Glaisher's tables, it is easy to find the relative humidity corresponding to these readings. The dew-point is calculated by use of the following formula:

Dew-point $= Td - F\ (Td - Tw)$, where Td and Tw stand for the temperature of the dry and wet bulbs, and F for the factor

opposite the dry-bulb temperature found in Glaisher's tables. The following is an example:

$$\text{Dew-point} = 62 - 1{\cdot}86\ (62 - 58)$$
$$= 62 - 1{\cdot}86 \times 4 = 62 - 7{\cdot}44 = 54{\cdot}56^\circ\ \text{F.}$$

Knowing the dew-point and the temperature of the air, and having access to hygrometric tables, the relative humidity can be readily determined, and is—

$$\frac{\text{weight of a cubic foot of vapour at the dew-point}}{\text{weight of a cubic foot of vapour at dry-bulb temperature}} \times 100.$$

In a properly ventilated room there should be a difference of at least 3° or 4° between the dry and wet bulbs, and if the room is adequately warmed, that of the dry should be about 60° F. In certain branches of the textile industry the manufacturing process must be conducted in a humid hot atmosphere; but all authorities agree that in the interest of the worker the temperature of the wet-bulb thermometer suspended in the room should never exceed 70° F.

Where rooms are heated by stoves, the air is liable to become too dry, and so irritating to the throat; in such cases it is necessary to prevent the relative humidity falling below 55° by taking care to add moisture artificially if the difference between the two tends to exceed 9°.

Rainfall.—Knowledge of the total amount of rainfall at a place and its distribution throughout the year is important in ascertaining its suitability as a place of residence or as a health resort. Rainfall is expressed in inches, and the rain-gauge is the instrument employed for recording its amount. The funnel-shaped collecting surface of the gauge is placed 1 foot above the ground in an open space. The rain is delivered from the funnel into a collecting vessel contained within the hollow metal cylinder supporting the funnel. Readings are taken by pouring the rain collected into a graduated glass, each of the small divisions on its sides indicating $\frac{1}{100}$ inch of rainfall. The graduation is effected by determining the area of the funnel mouth in square inches. For example, suppose this area is found to be 50 square inches, then, if rain to a depth of 1 inch covered this area, the volume would be 50 cubic inches, and the

level of the surface of the water when this volume is poured into the measuring glass would indicate 1 inch of rainfall. The distance from the bottom of the glass to the level is then divided into one hundred equal parts. Accurate records of rainfall extending over a number of years are necessary data in considerations relating to water-supply and sewage disposal.

The amount of rainfall varies in different parts of the kingdom from 20 inches to 154 inches, the average being about 30 inches. Mountainous regions near the coast are wet, the moisture from the sea breezes being condensed when brought into contact with them. It is rare for the rainfall to amount to 1 inch in any one day.

Barometric Pressure.—The pressure of the atmosphere shows wide variations, depending on the amount of aqueous vapour contained in it. When dry air takes up moisture it expands, and this expansion is such that a volume of the moist air is lighter than a corresponding volume of dry air, in spite of the moisture which has been added to it. This explains the fact that increasing amount of moisture in the atmosphere and the approach of rain is indicated by a fall of barometric pressure.

The movement of the air depends to a large extent upon the different barometric pressure prevailing at different regions on the earth's surface. Wind intensifies cold by promoting evaporation from the body and in this country the trying and injurious effect upon the health of the cold east winds of the early spring is well recognized. Elderly people, and especially those subject to bronchitis, suffer severely.

The weather forecasts which central meteorological offices are now able to issue depend to a large extent upon a knowledge of the barometric pressure prevailing at various points over a very extensive area. Barometric readings taken at the same time are telegraphed to the central station, and then lines, or "**isobars**," are drawn through places having the same pressure. These lines usually form concentric circles, and a chart showing such lines is called a **synoptic chart.** In making the lines in this country differences of $\frac{1}{10}$ inch between the various barometric pressures are recorded. Where the lines are close together or far apart, the "gradient" is said to be steep or shallow respectively. A **cyclonic system** has at its centre the lowest, and at its

periphery the highest, barometric pressure. In the case of an **anticyclone** the opposite is true. These systems often cover the greater portion of North-Western Europe, and in the case of the anticyclones may remain stationary for days or weeks; but cyclones travel rapidly from west to east, so that the barometric pressure at a place changes rapidly.

Anticyclones are associated with fine, dry weather, usually hot in summer and cold and frosty in winter. Cyclones, on the other hand, mean cloudy skies, wind, and rain.

To restore atmospheric equilibrium the air tends to move from the regions of high to those of low barometric pressure, so that the movement is towards the centre of the cyclone and away from the centre of the anticyclone. The direction of the movement of the air is also influenced by the rotation of the earth on its axis, the air being carried round at the same rate as the earth's crust at each part of the surface. It is obvious that this movement is greatest at the Equator and is nil at the Poles. The result is that the wind in these systems does not blow directly into or from their centres, but has a direction more or less parallel to the isobars.

The velocity of the wind is usually measured by means of Robinson's **anemometer.** This instrument consists of four revolving arms, to the extremities of which are attached hollow cups, against the concave surface of which the wind impinges and causes the arms to revolve. The arms travel at about one-third of the rate of the wind, and their rate of motion is recorded on a dial with which the instrument is provided.

For measuring the rate of air currents in shafts and at air inlets and outlets, use is made of Casella's air meter. The rate of movement of the vanes in this apparatus is shown on a dial, the hands of which are allowed to travel when the vanes have attained their maximum velocity.

Atmospheric pressure is measured by means of a mercurial barometer. When a glass tube about 1 yard in length and closed at one end is filled with mercury and inverted without entrance of air in a trough containing the same metal, the mercury in the tube falls until the height of the column is such that it balances the pressure of the atmosphere exerted upon the mercury in the trough. Barometric readings in this country

are expressed in inches and fractions of an inch, the use of the vernier facilitating accurate returns. The barometer scale is divided into $\frac{1}{10}$ and $\frac{1}{20}$ of an inch, or, in other terms, indicates divisions of 0·1 and 0·05 of an inch. Twenty-five divisions of the small sliding vernier scale are equal to twenty-four of the 0·05 divisions on the large scale, so that each division of the vernier is $\frac{1}{25}$ of an inch less than the 0·05 division on the large scale—in fact, the vernier shows differences of $\frac{1}{25} \times 0{\cdot}05$ inch $= 0{\cdot}002$ inch. In taking a reading the lower edge of the vernier is made to form a tangent with the upper convex surface of the mercury. The number of 0·1 divisions above the nearest figure of the main scale at which the lower edge of the vernier stands is noted, and also the presence or absence of a 0·05 division. If the edge of the vernier is not in the same horizontal line with one of these divisions, then the reading of the fraction of an inch above that of the main scale is arrived at by finding the number of divisions of the vernier. It is necessary to count upwards until a line of the vernier is in the same straight line with a line of the main scale, and then multiply 0·002 by this figure. The result is then added to the rest of the reading. A short practical use of a vernier will demonstrate why this process gives true results.

In aneroid barometers the varying pressure of the atmosphere is recorded by the effects produced upon a metallic box nearly exhausted of air. The changes are recorded by a dial hand acted on by a spring, which responds to the alterations of pressure. In the graduation of the aneroid barometer comparative readings of a standard mercury barometer are required.

Influence of Atmospheric Pressure on Health.—The organs of the body, and especially those concerned in respiration and circulation, are adapted to the normal atmospheric pressure of 30 inches of mercury, or about 14 pounds to the square inch. The vital processes, however, can be carried on when this pressure is either reduced or increased within wide limits. The effects of lessening of the atmospheric pressure are experienced when, in mountain climbing, a height of 6,000 feet is reached. The usual symptoms are bleeding from the nose, quickened pulse, and a feeling of weight in the limbs. After a time these

symptoms pass off and the individual's general condition improves. The number of red blood corpuscles is increased, and this increase counterbalances the effect of the lowered oxygen pressure of the inspired air. When a great elevation is reached and the pressure of the oxygen very markedly reduced, death may result, as in the case of the ascent of the balloon "Zenith" to a height of 6,800 metres, where, of the three occupants, two died, and the third, although unconscious, afterwards recovered. The oxygen pressure at this height was only 7 per cent. of an atmosphere, or a little over one-third the normal amount. It is found that in well-ventilated diving-bells, caissons, etc., men can work exposed to a pressure of three or four atmospheres, without their health being affected, if they are healthy men of spare habit, and if the shifts are not longer than four hours. On entering the caisson the men may suffer from vertigo and pain in the ear due to the difference of pressure on the two sides of the membrana tympani, but as a rule this can be prevented by increasing the pressure in the middle ear by the act of swallowing. Danger arises if the workman too suddenly comes from the caisson into the open air. The symptoms that may then occur are nausea, vomiting, paralysis, muscular and articular pains, and are believed to be the effects of nitrogen which was in solution in the plasma at the high pressure, but which, with the return to normal pressure, escapes as bubbles into the blood and tissues. These symptoms usually abate when the person is recompressed and warmth and stimulants are applied. To avoid untoward effects, the workmen from the caisson enter a decompression chamber, in which the pressure is gradually reduced, usually at the rate of twenty minutes for each atmosphere.

Influence of Season on Disease.—The fact that the deaths from certain diseases are most numerous each year at certain periods is well attested by the Returns of the Registrar-General. The cause of this periodicity is difficult to explain, but in certain cases is evidently related to the temperature, humidity, etc., of the air. As a broad rule it may be stated that summer is the dangerous season to infants, winter to elderly people. In winter deaths from Apoplexy, Heart Disease,

Kidney Disease, Bronchitis, and Pneumonia are frequent, and here cold is probably an exciting cause.

Intestinal diseases prevail towards the end of summer and during autumn. The curve of incidence of Infantile Diarrhœa rapidly ascends during July, to reach its maximum point in the first week of August, after which it falls gradually through September and October. A wet summer is associated with a low mortality from Diarrhœa. Typhoid Fever increases during the autumn, and attains its maximum mortality in November. The curves of mortality from Scarlet Fever and Diphtheria are almost parallel to those of Typhoid Fever.

Smallpox, Whooping-Cough, Typhus Fever and Cerebro-Spinal Fever are most prevalent during the first four months of the year. In India, where Plague is now endemic, outbreaks of this disease show a marked relationship to season, and quite recently the researches of the Plague Commission have afforded an explanation of the phenomenon. As we shall see in our consideration of this disease, it is now believed that it is transmitted through the agency of rat-fleas. A census taken of the fleas found on rats has shown that their numbers vary with the season of the year, hot dry weather being unfavourable to their life. When fleas are abundant, Plague is prevalent, and with their decrease, the disease also diminishes almost *pari passu*.

Vitiation of the Air.—Air may be vitiated by particulate matter of organic and inorganic nature, and by gaseous impurities. The suspended matter consists mainly of dust carried up by air currents from the ground—soot, pollen, spores of fungi, salt crystals, and bacteria. The composition of dust varies with its source; that produced in the household and in textile workrooms is in the main of an organic nature, whilst that generated in pottery and steel manufactories and out of doors is largely mineral. The clouds of dust stirred up on our main roads and streets by motor traffic create a nuisance and danger to health scarcely less than that produced by smoke in certain manufacturing towns.

Bacteria in Air.—As a rule bacteria are absent from air collected over the ocean and on the tops of high mountains, and few are found in the air over fields in the country. The number present and the amount of dust in the air are closely

related. The open air usually contains less than one bacterium per litre, but in crowded rooms there may be fifty, and in dusty workshops several hundreds in this volume. A determination of the number gives little information as regards the ventilation of a building, since bacteria are not exhaled from the air passages during quiet breathing. By loud speaking, sneezing, and coughing, bacteria contained in droplets of mucus are sprayed into the air, and in the air of debating chambers streptococci derived from the throat have been detected. In this way Influenza, Diphtheria, Whooping-Cough, Tuberculosis, and the acute exanthemata are often transmitted. Pathogenic germs, when voided from the body, are contained in moist and sticky secretions, from which they are not readily detached until these secretions have become completely desiccated, and this process is fatal to the majority of them. We have already mentioned the fact that filterable viruses are remarkably resistant to desiccation, and therefore the viruses of Smallpox, Scarlet Fever, and Infantile Paralysis, may be conveyed in dust through the air just as clinical and experimental evidence has shown to be the case with the anthrax and tubercle bacillus. Bacteria, like other impurities, are washed out of the atmosphere by rain, and the watering of streets, by laying the dust, tends to keep the bacterial content of the air low.

The **gaseous impurities** of air are mainly derived from—(1) Respiration of men and animals; (2) combustion of wood, coal, gas, oil, etc.; (3) fermentation and putrefaction; (4) manufactories.

Respiration.—As will be seen from the following table, the process of respiration adds much carbonic acid and watery vapour to the air, and abstracts much oxygen; the adult absorbs daily by the lungs nearly two pounds of oxygen.

	Inspired Air.	Expired Air.
Oxygen.. ..	20·96 volumes per cent.	16·03 volumes per cent.
Nitrogen, argon, etc.	79·00 ,, ,,	79·00 ,, ,,
Carbonic acid ..	0·04 ,, ,,	4·4 ,, ,,
Watery vapour	Variable	Saturated
Temperature ..	Variable	That of the body (37° C.)

An adult during quiet breathing adds from 0·7 to 0·8 cubic foot of carbonic acid to the air per hour, but by exertion this is increased to 0·9 or even to 1·8, according to the severity of the labour. These numbers have been calculated as follows: On an average 17 breaths are taken per minute, and 500 c.c. (30·5 cubic inches) pass in and out of the lung with each act. $17 \times 30{\cdot}5 \times 60 = 31{,}110$ cubic inches $= \frac{31{,}110}{1{,}728} = 18$ cubic feet of air breathed per hour, and 4·5 per cent. of this is carbonic acid gas $= 0{\cdot}79$ cubic foot.

In a mixed audience of men, women, and children, the production of CO_2 per head per hour is taken as 0·6 cubic foot.

The air in a building vitiated by the process of respiration contains organic matter, and if ventilation is insufficient, feels stuffy, and has a disagreeable odour to a person coming in from the outside air. It is probable that air coming direct from the lungs does not normally contain organic matter, but that the latter is derived from the teeth, gums, tonsils, and stomach. The odour arises partly from the same source, and also from volatile fatty acids, etc., given off by the skin, and by clothing soiled by perspiration and other excretions. The evil effects of air vitiated by respiration is attributed by many to the presence of this organic material, and also to the absence of some unknown vital principle. When air containing such substances has been aspirated through pure distilled water, they are absorbed by the water, and are found to decompose potassium permanganate, and to contain nitrogen, and to blacken on ignition. This organic matter diffuses slowly, and, in order to destroy it, large volumes of fresh air are necessary; recently the addition of ozone (1 to 5 parts per million) has been introduced with this object. The effects produced by breathing air already vitiated by respiration are headache, lassitude, a feeling of discomfort and nausea, and lack of power to concentrate the mind. The continued breathing of such air leads to anæmia, and, by its debilitating effect on body and mind, predisposes the individual to Tuberculosis and other infective diseases. There are certain well-confirmed records of fatal results following the crowding of people into a small ill-ventilated space. The experience of the prisoners in the

Black Hole of Calcutta and of the steerage passengers on the steamer *Londonderry*, exemplifies this. This ship, on December 2nd, 1848, sailed from Sligo for Liverpool, and during a storm of a few hours' duration, it was necessary to shut up 200 steerage passengers in a cabin ($18 \times 11 \times 7$ feet) under closed hatches. When the doors were opened, 72 of them were dead. In such instances probably lack of oxygen is an important factor in producing the injurious effects, but such an explanation does not account for the disagreeable effects experienced in an ordinary ill-ventilated building. Reduction of oxygen to 20·65 per cent. by volume is seldom found even in the worst ventilated rooms, and it is well known that in ascending mountains an enormously greater reduction of oxygen pressure occurs without producing symptoms. The physical condition of the air has probably greater influence in producing the disagreeable effects than the chemical.

Certain experiments have shown that when the temperature of the room is kept low, and when the air is kept in circulation by means of fans, the mental and bodily torpor does not arise.

It is probable that the high temperature and the excessive moisture and stagnation of the air of crowded buildings prevent the loss of heat and of toxic waste products by the skin.

The amount of carbonic acid gas added to a room by respiration is quite insufficient to produce the evil effects of bad ventilation; but since the poisonous effect seems to increase more or less *pari passu* with the carbonic acid, the latter is taken as an index of the condition of the air. Although it requires the presence of pure CO_2 to the extent of 1 to 2 per cent. to produce any disagreeable effect, it is found that when, as a result of respiration, the air of a room contains 0·06 per cent. of this gas, it feels stuffy to a person coming into it from the open air. An estimation of the amount of carbonic acid gas in a room is important in determining the adequacy of the ventilation. It is probable that there may be present in fresh air some constituent of vital importance to metabolism which has eluded the chemist and the physiologist. Certain it is that life out of doors imparts a vigour and a sensation of health and well-being that is too often not experienced by those following indoor occupations.

Combustion.—This is essentially a process of oxidation of the carbon, hydrogen, sulphur, etc., contained in the fuel. When coal is burnt, there result compounds of carbon and sulphur and water, together with more or less free carbon (soot), usually 1 per cent. Some idea of the degree of vitiation of the air which results from combustion is grasped when it is stated that the burning of one ton of coal adds three tons of carbonic acid gas to the atmosphere. Carbon monoxide arises when combustion is imperfect. Sulphur is present in coal to the extent of 1 to 5 per cent., so that chimney-smoke contains sulphurous and sulphuric anhydride, ammonium sulphide, and occasionally carbon disulphide.

As wood contains no sulphur, and coal-gas comparatively little, the combustion of these substances is not so vitiating in its effects as that of coal. Moreover, in the case of gas there is practically no unconsumed carbon set free, so that the use of gas-fires would mitigate the smoke nuisance of towns.

Coal-gas is produced by the destructive distillation of coal in the absence of air, the resulting gases being purified by condensation and by passing them through coke scrubbers to remove compounds of tar, ammonia, and sulphur. The resulting "gas liquor" is the mother substance of much of the ammonia of commerce. The crude gas is then passed over a mixture of quicklime and hydrated oxide of iron, and in this way carbonic acid gas, sulphuretted hydrogen, and carbon disulphide are completely absorbed or reduced to a mere trace. Since the products from gas-burners usually escape into the air of an apartment, it is most necessary in the interests of health that the amount of sulphur contained in the gas should be exceedingly minute—sulphuretted hydrogen being absent, and other compounds of sulphur not exceeding 20 grains per 100 cubic feet.

Dr. Haldane has shown that it is the sulphur compounds and not those of carbon that are responsible for the headache and depression produced by the breathing of air vitiated by the products of coal-gas illumination. It is found that the addition of 3 or 4 parts per 1,000 of pure carbonic acid gas to the air of a room produce no injurious effect; but that when this percentage is attained by combustion of coal-gas, symptoms

arise and must be credited to sulphur compounds and not to those of carbon.

The burning of a cubic foot of coal-gas produces 0·5 cubic foot CO_2. An ordinary flat flame burner consumes 5 cubic feet of gas per hour, but the use of an incandescent mantle reduces the consumption almost by one-half.

In cases where the products of imperfect combustion gain access to a room as from a defective flue, poisonous symptoms may arise among the occupants. Sore throat, headache, and malaise are complained of, and, where carbon monoxide is present to the extent of 0·4 per cent., a fatal issue may ensue. This gas combines with the hæmoglobin of the blood, and prevents the red blood corpuscles from carrying oxygen to the tissues.

Fermentation and Putrefaction.—These processes are attended by a consumption of oxygen, and are productive of gaseous compounds of carbon, sulphur, and nitrogen. Bacteria resolve the complex molecules of organic matter into such simple gases as ammonia, ammonium sulphide, carbonic acid, marsh gas, sulphuretted hydrogen, etc. Evidence of this process is shown by the high content of ground air in carbonic acid, and by the ammonia and sulphuretted hydrogen detected in the air over cesspools and manure pits. Sewer air, with the composition of which we deal at greater length in another chapter, is vitiated by these gases. In the shafts of old wells the increase of carbonic acid and the decrease of oxygen may be so marked that men entering them succumb. A sudden decrease of the oxygen content to 8 per cent. or lower produces convulsions and death by asphyxia. It is probable that 30 per cent. of carbonic acid gas has to be attained before the air containing it is directly poisonous. At a depth of 13 feet Fodor found in the ground air 14 per cent. of CO_2 and 7·58 per cent. of oxygen.

Manufactories vitiate the air either by the gases, fumes, vapours, and effluvia, or by the dust of an organic or inorganic matter generated in the process. In the interest of the operatives the State enforces the adoption of certain measures to mitigate the dangers to health incurred.

Alkali, chemical, bleaching and gas works add to the air

hydrochloric acid, sulphurous and sulphuric anhydride, sulphuretted hydrogen, etc. Furnaces yield carbonic monoxide and carbon dioxide, and the same gases emanate from cement works and brickfields. Copper smelting and brass founding produce respectively arsenical and zinc fumes. In various stages of cotton, linen, and woollen manufacture organic particles are added to the air. In wool-sorting the dust may contain spores of anthrax bacilli. The various offensive trades in which animal remains are handled are liable to add objectionable effluvia to the atmosphere.

Workers in stone and clay and steel are exposed to irritating dust particles, and may suffer as a consequence from diseases of the lungs—*e.g.*, Siderosis in the case of miners, masons, bricklayers, quarrymen and potters, china scourers, cutlers, file and tool makers. A fibrotic condition of the lungs is produced, followed in many cases by Pulmonary Tuberculosis.

White-lead workers, painters, plumbers, etc., by inhaling and swallowing oxide of lead, often suffer from Lead Poisoning.

CHAPTER VI

SOIL

The physical and chemical constitution of a soil and its bacterial content have a distinct relationship to the health of a community. Water-supply, building-sites, disposal of sewage and of the dead are a few of the public health problems associated with soil.

Surface soil consists of mineral and organic matter. The organic matter is derived from the decaying remains of plants and animals, whilst the mineral matter is derived from the rocks composing the earth's crust.

The rock formations of the earth are of three kinds—**Igneous, aqueous,** and **metamorphic.** The igneous were derived directly from the original molten matter by crystallizing out as it cooled, and are built up of silica, alumina, lime, oxide of iron, sodium, potassium, and magnesium. Examples of this formation we have in basalt and granite. The aqueous formations are derived from the depositions of substances suspended or held in solution in water, and in the same class are put certain organic strata derived from plants—for example, coal, lignite, bitumen. The aqueous or sedimentary rock formations may consist of clay (argillaceous), sand (arenaceous), limestone (calcareous), or chalk, which is composed mainly of the mineral skeletons of foraminiferæ.

Metamorphic rocks are rocks that have undergone change *in situ*, several strata having been fused together or some other chemical change produced—*e.g.*, slates and marbles, produced from clay, limestone, and sandstone. The igneous and metamorphic rocks are hard, almost impervious, and consist mainly of silicates; whilst the aqueous or sedimentary rocks are softer, more porous, and, in addition to silicates, contain carbonates and oxides.

In producing an admixture of the superficial organic matter and of the deeper-lying mineral matter of which soil is composed, various influences are at work. There is the physical action of water and air and the chemical action of the carbonic acid gas and oxygen contained in them. Weathering of the rocks results, and there is a breaking down into clay (aluminium silicate), silica, carbonates of calcium, magnesium, iron, etc.

Burrowing animals—*e.g.*, worms, moles, rabbits, etc.—bring mineral matter to the surface, whilst the rain carries organic matter, and the products of its decomposition, under. By the process of putrefaction and fermentation, bacteria convert organic material into ammonia compounds, sulphuretted hydrogen, and carbonic acid gas. Certain nitrifying bacteria in the soil oxidize ammonia to nitrous acid, which combines with such a metal as sodium, potassium, calcium, or magnesium, to form a nitrite, and then by the action of another group of bacteria the nitrites are converted into nitrates.

Humus, or mould, is largely the result of bacterial action, in which certain organic acids—humic, ulmic, crenic, and apocrenic—are formed. We shall presently see that this acid-forming power of bacteria may impart a plumbo-solvent action to the water collected from an area—*e.g.*, bogs, where it is prominent.

Soil influences the health of people dwelling on it mainly by the water, air, and bacteria contained in it. The conformation of the ground also is an important factor in determining the nature of building-sites and the facilities for drainage of a town, whilst the climate is influenced by the presence or absence of mountains. In the tropics vegetation, and especially brushwood and jungle, by affording suitable breeding-ground for noxious insects and other animals, has an important bearing on hygiene. Some districts have been made less malarious by the drying of the soil effected by the planting of trees which transpire freely—*e.g.*, *Eucalyptus globulus*.

The amount of moisture and water in soil is an important consideration in considering the suitability of a building-site. Water has a high specific heat; therefore a soil containing much water is cold. A certain amount of the rain falling on the

ground is absorbed by the soil particles, whilst another fraction percolates between them and eventually forms a continuous sheet of underground or **subsoil water,** the interstices of the soil being filled with it. The level of the surface of the underground water is the same as that of the water in wells, and can be ascertained by means of floats in the wells. The depth of the subsoil water is principally determined by the amount of rainfall and the distance of an impervious stratum from the surface. The subsoil water has a slow movement towards the nearest watercourse, the rate varying with the nature of the ground, the gradient, and the condition of the outlet; the rate may be as little as 15 feet per day. If the underground water is polluted by the sewage of cesspools, the wells in its course are rendered dangerous.

The pores of the soil above the level of the underground water are occupied by air—the ground air—which differs from the surface air in containing a larger amount of carbonic acid gas and a smaller quantity of oxygen. Fermentation even in unpolluted soil is constantly generating carbonic acid gas, and where the soil is contaminated with sewage, sulphuretted hydrogen, ammonium sulphide, and ammonia are also found. A porous soil readily allows these emanations to escape, and a rise of the subsoil water forces them out. The temperature of the soil and the amount of water present influence the rate of decomposition. At 3 feet from the surface ground air often contains 2 per cent. carbonic acid gas and 19 per cent. oxygen.

We have already referred to the nitrifying bacteria present in soil. In virgin earth harmless saprophytic bacteria are present, but in soil contaminated with the excreta of men and animals, not only the bacteria which are normal inhabitants of the alimentary canal—*e.g., B. coli, Streptococcus fæcalis, B. enteritidis sporogenes*—may be present, but also such pathogenic bacteria as the *B. typhosus, B. dysenteriæ, Vibrio choleræ, B. tetani, B. anthracis.*

Relation of Certain Diseases to Soil.—(1) Diseases due to spore-forming bacteria may be contracted through soil containing these germs being inoculated into men or animals—*e.g.,* Tetanus, Malignant Œdema, and Anthrax.

(2) When pathogenic germs contained in the excretal matter of men mix with soil, they may survive in it for long periods, and then infect man through water and food contaminated with it.

According to Firth and Horrocks, cultivated typhoid bacilli can survive for seventy-four days in soil, and the germs were recovered by them from soil which three or four weeks previously had been smeared with typhoid stools.

Pettenkofer formulated a classical theory according to which soil played an important part in determining the occurrence of epidemics of Enteric Fever, Cholera, and Malaria.

Certain diseases are communicated directly from the patient, whilst the virus of Malaria, Cholera, Enteric Fever, according to Pettenkofer, required to complete a ripening process in the outside world, especially in soil, before becoming infective. For this ripening process a moist aërated sewage-polluted soil was most suitable, and this condition occurred on a sudden depression of the level of the subsoil water. How the soil acted was not clear: according to some, by the bacteria increasing in virulence from growth in this medium; whilst others saw an explanation in Nägeli's diblastic theory, according to which it was assumed that the soil produced specific fungi which symbiotically assisted the causal micro-organisms in overcoming the resistance of the normal human body. We now know that the virus of Malaria does not pass a cycle of its existence in soil, but in the bodies of mosquitoes; and in the case of Cholera and Enteric Fever few now adhere to Pettenkofer's view, most believing that Pettenkofer's facts can be explained by the opportunities afforded for pollution of water and food. Whilst epidemics at Munich and Buda-Pesth coincided with a low level of the subsoil water, at other places there was no such coincidence; and at Bombay, Koch observed that the amount of Cholera was the same among people dwelling on alluvial soil and those on primitive rock.

The fact that epidemics of Cholera and Enteric Fever rarely occur on ships is to be explained by the cleanliness observed and by the facilities for the rapid disposal of excreta rather than by the absence of soil. Whilst Pettenkofer and Emmerich swallowed Cholera cultures without suffering, others have acci-

dentally contracted the disease in laboratories in towns where Cholera was not present.

According to Ballard, the temperature of the soil is important with regard to the incidence of Infantile Diarrhœa. It was noticed by this observer that the mortality curve of Infantile Diarrhœa began to rise the same week in which the 4-foot earth thermometer reached a temperature of 56° F. Ballard believed that the infective agent in this disease at this temperature developed in the soil, and from it infected food. It is probable that this temperature of the soil is simply an index of a temperature of the interior of houses favourable to the growth of bacteria in food and milk which produce the disease. Unclean soil is usually associated with other insanitary conditions, and it is difficult to decide which factor is the more important in determining Diarrhœa prevalence. The spread of Dysentery and Diarrhœa is favoured by like conditions.

(3) In the case of Malaria and Yellow Fever a soil suitable for the breeding of mosquitoes, such as is found in low-lying ground beside rivers, is one of the most important factors in determining the incidence of these diseases.

(4) It is usually believed that damp dwellings situated on damp sites predispose to Diphtheria, although there is no evidence that the diphtheria bacillus is either an ordinary or occasional resident in the soil. Probably the influence is indirect; the chilling effect produced by evaporation of moisture in these dwellings leads to catarrh of nasal and buccal mucous membranes, just as it predisposes to Bronchitis and Enteritis. Apparently the chilled mucous membrane allows pathogenic bacteria to overcome the normal resistance of the body. On the other hand, Newsholme, from an analysis of the incidence of Diphtheria and the amount of rainfall, concluded that Diphtheria was favoured by the occurrence of three or four consecutive dry years.

(5) According to the investigations of Bowditch in America, and of Buchanan in England, draining of the soil lowers the phthisis death-rate. Undoubtedly the provision of dry dwellings is an important weapon in the crusade against consumption.

(6) Acute rheumatic fever, erysipelas, puerperal fever, and

septicæmia show a similarity to each other in their prevalence in years of sparse rainfall. A dry, warm soil with low level of ground water is an associated phenomenon in years when these diseases are unduly common. How the condition of the soil affects the incidence of these diseases is unknown, since there is no evidence for the theory that their specific contagia lead a saprophytic life in soil.

(7) Goitre and Calculus have for many years been attributed to the consumption of water derived from limestone. Investigation, however, does not support the view that hardness of the water is a factor in the causation of calculus. Stone is frequent in India among people consuming soft water. Many authorities hold that Calculus must be considered as being due to a defect of metabolism resulting from an inherited idiosyncrasy or from diet and mode of life. The recent work of McCarrison on the distribution of Goitre in Chitral, Gilgit, and Nagar has confirmed the view regarding the association of the disease with the drinking of water derived from limestone outcrops, and has thrown some light on the causative agent.

(8) Lead-Poisoning due to the plumbo-solvent action of water derived from moorland areas has been frequently described, and one cause of the solution of the lead is the presence in the water of organic acids derived from the growth of certain acid-forming bacteria in peat.

(9) Various parasitic worms are conveyed to man through the agency of soil. The ova of *Ascaris lumbricoides* and of *Tænia echinococcus* often reach water and vegetables from polluted soil, and the embryo of *Ankylostoma duodenale* can develop in moist soil if the temperature is sufficiently high, and can, when the soil is brought into contact with the epidermis of man, penetrate through the uninjured skin to the underlying capillaries and lymphatics; and it is probable that something similar happens in the case of infection with the *Bilharzia hæmatobia*.

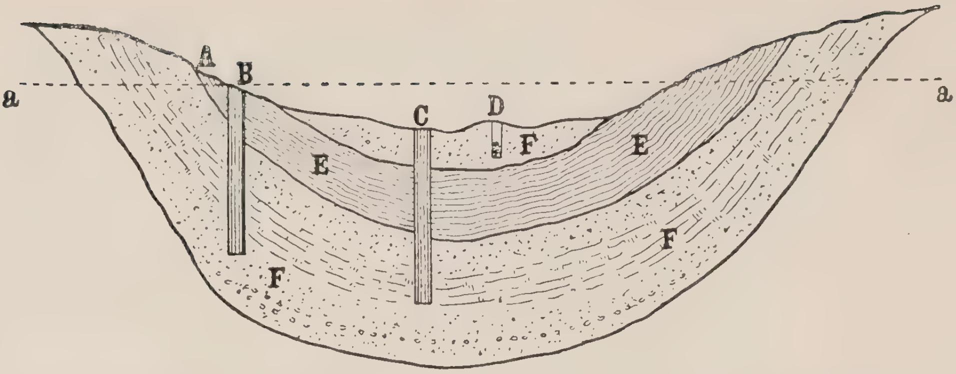

FIG. 17.—Section of earth's crust, showing impervious stratum E, E; intermittent spring at A; artesian wells at B and C, and shallow well at D. a, a, water-level in deep pervious strata F, F.

(*From* Egbert's "Hygiene and Sanitation.")

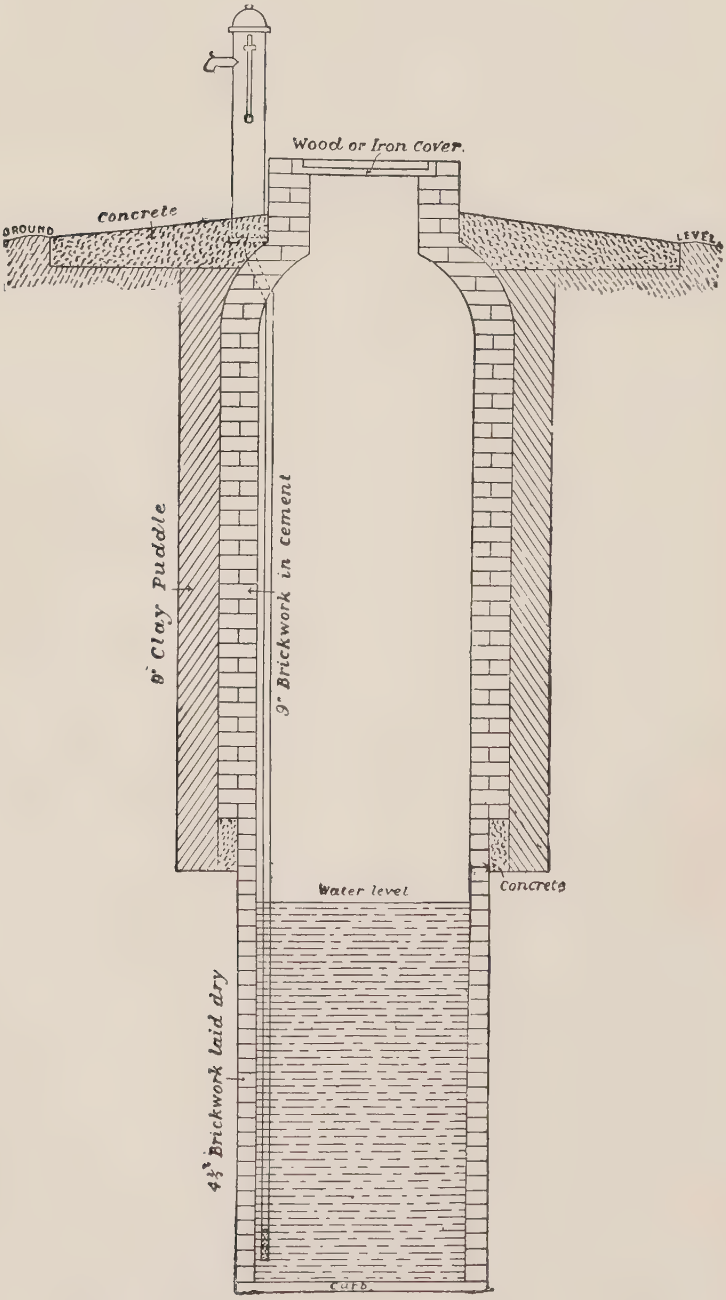

FIG. 18.—Construction of a Shallow Well.

(*From* Thresh's "Examination of Waters and Water-Supplies.")

CHAPTER VII

WATER

WATER used for drinking purposes, whatever its source, is derived from the condensation as rain or snow of watery vapour formed by evaporation on the earth's surface. Part of the rain that falls runs off the surface of the ground as rivers and streams, part is at once evaporated or absorbed by vegetation, and the remainder passes down into the layers of the earth's crust until held up by an impervious stratum. This ground or subsoil water is the source of supply for springs and wells. In some cases as much as 90 per cent. of the rain may percolate into the earth, in other cases practically none. The nature and slope of the soil, season of the year, amount of rainfall, etc., are important factors in determining the relative amounts of the three portions. On an average, six-tenths of the rainfall is available for storage.

The depth at which the underlying impervious stratum is situated will largely determine the distance between the surface of the ground and that of the sheet of ground water. The **ground water** fills up the interstices of the soil, and slowly flows towards the nearest watercourse. The rate of movement varies with the gradient, the texture of the soil, etc.; on an average it is only about 20 feet per day.

Wells are shafts sunk to tap the underground water. The distinction between a shallow well and a deep well is that the latter passes through at least one impervious stratum. The position of water-bearing strata—*e.g.*, chalk, sandstone, gravel—varies at different points of the earth's surface. At certain places these strata come to the surface (outcrop), and here they obtain the supply of water which fills up their interstices even at points where an impervious layer comes between them and the surface. Such deep water has usually travelled a long dis-

tance from the outcrop of the stratum, and therefore any impurities of the original water have had time to be completely removed. In the chalk, fissures sometimes stretch for miles, and there are many instances of the pollution of chalk water by the passage along the fissures of sewage from the surface of the ground. As means of ascertaining if a cesspool or other collection of sewage is responsible for the contamination of a deep-water supply, the following devices have been employed:

Adding fluorescein or other dye to the sewage, and then after an interval examining the specimens of well-water. Instead of a dye, sodium chloride may be added in large amount, the chlorine content of the well water being ascertained before and at various intervals after the addition. A third method is to employ cultures of the *Bacillus prodigiosus*, which can be readily found in the well water if they have passed through to it from the suspected source of pollution.

The outcrops of a water-bearing stratum are sometimes at a high level relative to the longitudinal course of the stratum; if then the stratum is saturated with water and a shaft or fissure passes down from the surface of the ground and reaches this water in the lower part of the stratum, the water will rise in the shaft to a height corresponding with its level in the stratum. If the water reaches the surface of the ground, it is called an **artesian well.** A **spring** results when the outcropping of an impervious stratum causes the subsoil water coming from a higher level to come to the surface. Fig. 17 illustrates the relationship of wells and springs to the geological strata.

Amount of Water required.—Water, being required not only as drink for man and beast, but also for cooking, washing, carriage of excreta, and various manufacturing processes, should be supplied to towns in liberal quantities. The amount supplied per head to different cities varies very widely, and no doubt a very considerable proportion of the 200 to 300 gallons per head supplied to some American cities is wasted. In this country an average of 35 gallons per head per day is found sufficient. The introduction of meters in the course of the mains in the different districts of a town has in many instances located and prevented the waste of water as the result of leaks in the pipes and carelessness on the part of householders.

Mode of Supply.—The rain collected from roofs is often used for washing, and in some districts also for drinking purposes. In order to remove soot and dust, use may be made of Roberts's rain-water separator, which is attached to the rain-water pipe, and allows the first part of the rainfall to run away, but after a time tips over and directs the remainder into the collecting vessel. Another method is to have two receptacles which are connected together by a pipe: the first or collecting receptacle is empty; the second or delivering receptacle has its bottom filled with gravel or sand, and the water entering at the bottom is compelled to pass through this filtering layer before reaching the outlet tap situated at a high level.

Rain, being distilled water, is very soft, and in the country and remote regions is very pure. In towns it takes up, in addition to the particles of dust and carbon, traces of ammonia, carbonic acid gas, sulphurous acid, and numerous bacteria. When rain water is used merely to supplement the ordinary supply, it is usually collected in wooden barrels, and these are quite satisfactory. Rain water has a very solvent action on lead, zinc, or iron tanks, so that if cisterns are used for storing such water, it is well to line them with cement. If rain water is used for drinking, care should be taken to see that it has not come into contact with lead either on the roof or in the collecting vessel.

Surface Waters.—The purity of surface water is, of course, dependent on the character of the ground from which the water is collected (**catchment area**). The danger to a water-supply is dependent on the amount of excretal matter, especially that of human origin, added to it. The first safeguard is to have a clean catchment area, such as is furnished by unpopulated, hilly, or mountainous regions, or by areas the farms of which have been acquired and the people removed. Valleys often act as impounding reservoirs, their outlets being closed by an artificial embankment.

Lakes are natural reservoirs, and have been used as supplies by many cities—*e.g.*, Glasgow, Chicago. Precautions against the pollution of such supplies by steamboats are necessary.

The suitability of a river as a source of supply is influenced by the extent to which it is subjected to pollution by villages

and towns along its course. As a rule river water requires treatment before it can be supplied with any degree of safety.

In addition to impounding reservoirs, there are compensation reservoirs into which a certain amount of the turbid water collected during heavy rainfall can be directed, and afterwards passed on to the mill-owners and others lower down the valley who have claims to a certain amount. The site of all reservoirs should be at such a level that the highest floors of the houses can be supplied by gravitation. Where rivers are used, the water has frequently to be pumped up into the reservoir.

Reservoirs should hold at least 150 days' supply. In planning for the supply of a community with surface water, it is necessary to know the amount to be supplied per head, and then to ascertain the area of the catchment area required, taking into consideration the minimum annual rainfall, the proportion of rainfall available for storage, and the longest period of drought. In such calculations Pole's formula is useful—viz.: $x = 62\ A\ (\frac{4}{5}\ R - E)$, where x = the total yield of water in gallons; A = the area of the gathering ground or catchment area in acres; R = the mean rainfall of the three lowest consecutive years; E = the loss of water by evaporation, waste, and percolation; this varies from 10 to 20 inches. Cities supplied with sewage-polluted river water require large storage reservoirs. The processes, as pointed out by Houston, which make for the purification of water under storage conditions, are chiefly (1) sedimentation, (2) equalization, and (3) devitalization. Waters vary from time to time as to their content of pathogenic bacteria, and therefore storage has a "levelling" effect on the supply. During storage pathogenic bacteria disappear, and probably one month is sufficient to produce this result.

From the impounding or storage reservoirs the water, unless the catchment area is above suspicion, should be led to filter-beds, and then, after filtration, to small covered and ventilated service reservoirs, which conduct it into the mains. The embankments of storage reservoirs are usually of puddled clay in their interior, and their sloping sides are covered on the inside with dressed stones, and on the outside with vegetation. The roots of shrubs or trees would be liable to weaken the bank. Service reservoirs are lined with cement.

Subsoil Waters.—Surface wells supply the majority of the rural population in these islands. The character of the water derived from them depends largely on their situation with regard to cesspools, manured ground, etc., and on the porousness of the soil intervening. The model by-laws of the Local Government Board suggest that a privy and a cesspool should not be nearer a well than 50 feet and 100 feet respectively. The area drained by a well in ordinary soil is said to be a circle whose radius is equal to four times the depth of the well. The position of the well should be at a higher level than any collection of excrement, but even in such cases a sudden depression of the level of the water in the well resulting from pumping may cause a current from a cesspool towards the well. During drought fissures may be formed in the soil which allow the passage of pollution. A most important means of safeguarding the water in a well is to provide it with an impervious lining consisting of brickwork set in cement, and backed with a layer of puddled clay. At the top there should be a coping to exclude surface washings. Their situation largely determines the character of spring waters, and the considerations that apply to wells equally apply to springs. It is necessary at the point where the spring issues to protect it from surface contamination.

Deep waters are usually very free from organic matter. They very often contain large amounts of calcium and magnesium salts, but not sufficient to impair the palatableness of the water. They are often sparkling, and contain much carbonic acid gas. Such waters as a rule are wholesome, but, being very hard, may require to be softened before being supplied.

Diseases caused by Impure Drinking Water.—Waters rich in calcium and magnesium salts may give rise to Dyspepsia and gastro-intestinal irritation to those unaccustomed to their use. There is no evidence that hard waters produce urinary calculi. Salts of iron in a water are capable of causing Constipation, but since very minute quantities give an unpleasant taste to the water, other supplies are quickly substituted, or the iron is removed from the water by free aëration resulting in its precipitation. Lead, copper, zinc, and arsenic have sometimes been found present in sufficient amounts to cause poisoning.

River water when turbid at flood-time has caused Diarrhœa apparently by the mechanical irritation of particles of clay and mica suspended in it.

The ova of the parasitic worms *Tænia echinococcus, Ascaris lumbricoides, Filaria medinensis,* and possibly the *Bilharzia hœmatobia,* may have water as their infective vehicle.

The association of Goitre with drinking water has been known for centuries, and recent experimental work has substantiated the importance of water from limestone and dolomitic rocks in the etiology of the disease. Major McCarrison, I.M.S., from experiments conducted on himself and volunteers in the Gilgit and Chitral valleys, concluded—(1) Thyroid enlargement can be produced in a few weeks by suspended matter separated by filtration of goitre-producing water through a Berkefeld filter; (2) thyroid enlargement cannot be so produced when the sediment is boiled; (3) Goitre so produced cannot be due to mineral matter, but is due to a living organism; (4) while it cannot be positively stated that a Berkefeld filter removes the cause of Goitre, water so filtered cannot produce Goitre within fifty-six days.

Bircher found that Goitre can be produced in rats by natural water from goitrous springs, and that the toxic substances were destroyed by heat, but were not removed by a Berkefeld filter. What the nature of the agent is which produces the disease is still undetermined.

The chief diseases the agents of which are liable to be water-borne are those in which the intestinal tract is attacked—*e.g.*, Enteric Fever, Cholera, Dysentery, and Diarrhœa.

In order to produce these diseases the water must contain the specific agents; polluted water may be, and in the country generally is, consumed for long periods without harm resulting. Since specific pollution may be added at any time, such waters are potentially dangerous. As an example of the explosive nature of an outbreak of Typhoid Fever, the example of the experience of the town of Lincoln may be cited. This town in 1905 had a population of 51,000. Typhoid Fever appeared on January 22, and the number of cases reported in the first three weeks was 547; in the second three weeks, 200; in the third, 125; in the fourth, 87; in the fifth, 28; in the sixth, 6;

and in the last three weeks, 3 cases. In five months there were 996 attacks.

The danger involved in the consumption of polluted water and the safeguarding effect produced by filtration are illustrated by the Cholera epidemic at Hamburg in 1892. In Hamburg there were 16,957 cases of Cholera, and 8,606 deaths, whilst in the adjoining city of Altona, which also was supplied by polluted Elbe water, but which had an efficient system of slow sand filters, there were only 516 cases and 316 deaths. The death-rate in Hamburg was 13·4 per 1,000 of the population; in Altona it was only 2·1. It may be noted that many of the Altona cases probably contracted the disease in Hamburg, the cities being situated side by side.

Swimming-Baths.—The water used by numerous bathers soon contains a high bacterial content, derived not only from the surface of the skin, but also from the mouth and anus. In several outbreaks of Typhoid Fever swimming-baths have been strongly suspected of conveying the disease. The system of continual filtration and aëration and the addition of hypochlorites to the water has very much reduced the danger.

Purification of Water.—The **storage** of water not only leads to subsidence of the suspended grosser particles, but also allows time for the devitalization of excretal bacteria. This devitalization results from lack of food, from osmotic changes, from bactericidal effects of sunlight, and from the competitive activity of the water bacteria and flagellates. For simple subsidence probably twenty-four or forty-eight hours are sufficient, but for devitalization, three weeks or a month are necessary. The survival of excretal bacteria is influenced by the temperature of the water, cold being favourable. It is to be taken into consideration that although laboratory experiments seem to indicate that "uncultivated"—*i.e.*, bacilli derived directly from urine of a "carrier"—typhoid bacilli die out in water in two weeks (Houston), or at least inside the fourth week (Wilson and Dickson), still there may be great variation in the resistance of different strains, and some survivors may be able to adapt themselves to a saprophytic existence for a longer period. During storage the growth of algæ may impart an unpleasant fishy taste and odour to the

water. The principal algæ which have been found to produce these effects are different varieties of *Volvox*, *Uroglena*, and *Anabena*. The diatom *Asterionella* may cause a "geranium" odour in stored water. The growth of algæ may also interfere with the subsequent filtration of the water. Under skilled supervision these algæ troubles may be overcome by the addition of copper sulphate to the water in the proportion of 2 to 10 pounds per million gallons. The objectionable taste can be removed in a few minutes by oxidation produced by the addition of 2·5 to 5 pounds of permanganate of potash per million gallons. The faint pink tinge so produced very rapidly fades, and the consumer obtains a tasteless water, slightly browner in colour than normal.

Filtration.—For this purpose two forms of filters are now in common use—(1) slow sand filters, (2) rapid mechanical filters.

Sand filters consist of large water-tight tanks usually built of brick, lined with cement. At the bottom of these beds are channels and drains for conducting away the filtered water; above these drains is a layer of broken stones, and above the stones a layer of gravel 1 to 2 feet in depth. On the gravel is supported the filtering material, consisting of sand, and of at least 1 foot in depth. The finer the sand is the better suited it is for filtration. The average diameter of the sand-grains should be 0·3 to 0·4 millimetre. It requires a filter to be in use for one or two days before it becomes effective in the removal of bacteria. This allows time for the formation on the surface and between the superficial sand particles of a pellicle or scum, consisting of organic gelatinous matter—algæ, bacteria, and infusoria. It is in this layer that the bacteria in the water get entangled and absorbed. After the filter has been in use for about one month in summer or two months in winter the slowness of the filtration necessitates the removal of the thick blanket of organic matter on the surface. For this purpose the bed is emptied and the upper layers of sand scraped off to a depth varying from ½ to 1½ inches. The sand so removed is washed with filtered water and exposed to the air and afterwards replaced on the bed. After scraping, one or two days are allowed to elapse before the filtered water is permitted to enter the service reservoir.

Where the unfiltered water is frequently turbid from the presence of gross suspended matter, it is advantageous to pass the water through a series of beds of diminishing degrees of coarseness situated in tiers one above the other (*Filtres dégrossisseurs* of Puech and Chabal) before conducting it to the filter-bed proper. Sand-filters are continuous in their action, and the bed is covered with water usually to the depth of 3 feet. To get the best results, the rate of filtration should not exceed 4 inches, or 2·5 gallons per square foot of filter-surface per hour. An acre of filter-beds worked at this rate will yield about 2,500,000 gallons of filtered water daily. Properly constructed and regulated sand-filters should remove 96 to 99 per cent. of the bacteria present in the unfiltered water, and in 1 c.c. of the filtered water there should be not more than 100 bacteria. The chief function of filtration is the interception of micro-organisms, but the process also improves the physical and chemical characters of the water. The solids in suspension are completely removed, the free and albuminoid ammonias are reduced by about 50 per cent., and the reduction of oxidizable organic matter amounts to 30 per cent., and there is an increase of 25 to 30 per cent. in the nitrates.

Mechanical Filtration.—The use of mechanical filters has come into prominence in America, and at the present time numerous cities and towns in this country are supplied with them. A mechanical filter consists of a large drum, or cylinder, almost filled full of sand or quartz, which serve to remove the flocculent coagulum of aluminium hydrate which has been developed in the water before it reaches the filter. This artificial gelatinous precipitate in the mechanical filter serves the same purpose as the natural membrane on the surface of the sand-filter. To form the coagulum, sulphate of alumina in amounts not exceeding 1 grain per gallon is added, and in some cases is accompanied by chalk. The reaction which occurs is as follows:

$$Al_2(SO_4)_3 + 3CaCO_3 + 3H_2O = Al_2(OH)_6 + 3CO_2 + 3CaSO_4.$$

The water is driven usually by force of gravity through the cylinders, and the rate of filtration is rapid, one filter being capable of dealing with 250,000 gallons in the day. Of course,

the actual yield is determined by the size of the filter and the pressure. The filters require to be cleansed frequently, and to accomplish this the filling material is stirred up by revolving arms or other mechanical arrangement, and at the same time a stream of water which has been already filtered is driven through the filter. The amount of water used for washing usually does not exceed 3 per cent. of the supply filtered. Mechanical filters under skilled supervision are capable of reducing the bacterial content of the water by 98 per cent. They are specially adapted for the filtration of turbid river-water. Peaty water after passage through a mechanical filter has much of its yellowish-brown colour removed, and its plumbo-solvent powers are much reduced.

Household Filters.—A household filter should not be necessary in this country; its use implies that the individual or the community have not given the means of securing an abundant and wholesome supply of pure water proper attention. Filters which are capable of removing bacteria from the water are made of unglazed porcelain (Pasteur-Chamberland and Doulton), or of baked diatomaceous earth (Berkefeld). In these filters the water requires to be forced through either by means of gravity when they are screwed on to a main, or by use of a force pump. The filters are liable to be defective at the junction of the metal with the candle or bougie. They require frequent cleansing. This is done by scrubbing the outer surface of the candle with a brush and then boiling it or heating it to a red heat.

Filters of animal charcoal, asbestos, etc., render a water clear and sparkling, but do not remove bacteria.

The best safeguard against water-borne disease is to boil the water or to heat it to a temperature of 80° C. This method is especially suitable for armies on active service, and examples of its use are furnished by the water sterilizers of Griffith and of Forbes. Boiled or distilled water can be made palatable by shaking it up with air.

Chemical Treatment of Water.—One of the earliest examples of the use of chemicals in the treatment of water was Clark's method of softening a hard water. The distinction between a hard and a soft water rests on the difficulty or ease with

which a lather can be produced when soap is used for washing purposes. Soap is chiefly composed of the stearate, palmitate, and oleate of sodium or potassium. Substances in a water which are capable of decomposing the soap and uniting with the fatty acids prevent a lather being formed until the fatty acids have combined with all the soap-destroying agents in the water. Hardness is mainly due to salts of calcium, magnesium, and iron. Calcium and magnesium palmitates, oleates, and stearates are insoluble in water, and separate out as curdy flakes. Deep waters from chalk and limestone formations are hard, but there is a considerable reduction of the hardness on boiling the water. This is called the **temporary hardness,** whilst that which remains is known as permanent hardness. Temporary hardness is due to excess of CO_2 in the water, which renders calcium and magnesium carbonate soluble as bicarbonates. When the water is boiled CO_2 is driven off, and the carbonates are precipitated.

$$\underset{\text{Calcium bicarbonate.}}{CaH_2(CO_3)_2} = \underset{\text{Calcium carbonate.}}{CaCO_3} + CO_2 + H_2O.$$

It was found by Clark that the same result could be obtained by the addition of a definite amount of lime-water.

$$CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O.$$

The amount of lime required must be accurately determined for each supply.

The precipitated carbonates can be removed from the water by subsidence in settling tanks (Clark's), or by filtration through cloth under pressure (Porter-Clark's). This method not only softens the water, but has been shown by Hewlett and others to be a very effective means of removing bacteria.

The fur which forms on the inner surface of kettles and boilers is composed of deposited carbonates. The supply of a soft water to a town diminishes monetary expenditure not only on soap, but also on coal required to generate steam.

The permanent hardness which is due to salts of lime and magnesium held in solution by the solvent powers of the water itself can be reduced by the addition of sodium carbonate: thus—

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.$$

The sterilization of the drinking water of armies in the field can be effected by heat, filtration, or more readily by the use of chemicals. The chemicals which have been used are acid bisulphate of soda, iodine, bromine, permanganate of potash, and calcium hypochlorite. In recent years the powerful bactericidal properties of hypochlorites have been recognized. Hypochlorites act in virtue of the free chlorine contained in them. Their use is restricted by the fact that if the water contains much organic matter, a disagreeable taste is imparted to it. Water which is subjected to occasional contamination, such as deep chalk wells, can be sterilized by the addition of calcium hypochlorite without injury to its quality. The chlorine (a solution of bleaching-powder of known strength, reckoning 1 part of chlorine by weight to 3 parts of the bleaching-powder) is added to the rising main leading to the reservoir. At Cambridge it has been found that the amount of chlorine necessary to kill the whole of the non-sporulating bacilli in the water-supply of the town seldom rises above 1 part in 6 millions.

Ozone has been used in practice for the sterilization of large public supplies of water. The apparatus used consists of two parts—(1) the ozonizer in which air is charged with ozone by the silent electric discharge, and (2) the sterilizing tower in which the admixture of the air and water occurs, the ozone passing up and the water passing down. The excess of ozone quickly disappears from the water after destroying the bacteria present. The bactericidal power is greatly influenced by the quantity of oxidizable matter present. Sparking must be avoided in the ozonizer, otherwise oxides of nitrogen are formed which corrode the pipes.

Since 1906, when Nogier demonstrated that the rays emitted by a mercury-vapour lamp exerted a marked bactericidal effect on water bacteria, the problem of the sterilization of potable waters by means of the ultra-violet rays of light has attracted much attention. Since glass absorbs the actinic rays, the lamp is surrounded with a globe of fused silica. The lamp can be placed in the water or above it. The *B. coli*, *B. typhosus*, and *Vibrio choleræ* are killed in 10 to 20 seconds. The presence of traces of colloid matter, or

a faint turbidity in the water, greatly retards the bactericidal action. The rays seem to act directly on the bacteria without the formation of chemical compounds in the water.

Distribution.—From the service reservoir the water passes into the iron mains which distribute it over the district. The mains should be coated inside with Angus Smith's varnish, and should not be laid near sewers or gas-pipes. As a protection against injury by traffic and frost, they should be 2 feet from the surface of the ground. The intermittent system of supply in which the mains are filled with water only at certain hours of the day should be abandoned, and the constant system adopted. Objections to the intermittent system are—

(1) The drinking water must be stored in cisterns, and is therefore liable to contamination, whereas with the constant system the tap used for drinking and cooking purposes is situated on the rising main before it reaches the cistern; (2) pollution is liable to be sucked into the water-pipe; (3) corrosion of the pipes is favoured; (4) a supply of water is not always at hand to deal with an outbreak of fire. In the house lead pipes are usually employed, since they can be easily bent to suit any change of direction. Many cases of Lead-Poisoning have been traced to the presence in the drinking water of lead derived from pipes and cisterns.

Hot water dissolves lead more readily than cold water, and as lead solder is often found in connection with the hot-water cistern, it is never safe to use for cooking purposes water taken from the hot tap. Lead being a cumulative poison, its presence in water in greater amounts than $\frac{1}{20}$ grain per gallon is attended with grave danger to the consumers.

The **action of water on lead** is twofold: (1) an erosive action due chiefly to the oxygen, carbonic acid gas, ammonia, and nitrates in the water. Erosion is best marked when the pipes are new and their surfaces untarnished. In course of time the oxyhydrate of lead is converted into insoluble carbonates.

(2) A plumbo-solvent action specially due to the presence of acids in the water. Peaty water is particularly dangerous, since the organic acids produced by the growth of bacteria in the peat readily dissolve lead. To prevent the solution of the

lead it has been found advantageous (1) to filter the water through sand or silica; (2) to place in the filter-beds chalk or limestone; (3) to neutralize with sodium carbonate. The substitution of iron pipes for lead ones is the best safeguard. The use of tin-lined and glass-lined lead pipes has been tried, but junctions are difficult to make in such pipes, and if water escapes between the lead and the tin lining, galvanic action is set up and causes solution of the metals.

The examination of a drinking water should invariably involve a topographical inspection, a chemical, physical, and a bacteriological analysis. In interpreting the bacteriological and chemical findings, a knowledge of the local conditions is indispensable. It is necessary, therefore, in sending a specimen of water for analysis to give full particulars with regard to its origin. For a chemical examination a Winchester quart bottle filled with the water should be forwarded. For bacteriological examination as a rule not more than 200 c.c. are required. The bottle and stopper should be boiled, and, when filled, should be examined within a few hours. It is advisable to surround the bottle with ice during transit. The aim of the **chemical analysis** is (1) to ascertain the presence or absence of substances which are in themselves poisonous—*e.g.*, lead, arsenic, zinc, etc.; or, more commonly (2), to find indication of sewage pollution by a quantitative determination of certain constituents which are non-poisonous, but the presence of which beyond a certain limit suggests danger from accompanying bacteria. The chief tests relied on in determining whether a water is wholesome and safe are the determination of the free and albuminoid ammonia, the amount of oxygen absorbed by the organic matter present, the presence or absence of nitrites, and the amount of chlorine and nitrates.

Free ammonia is usually derived from sewage contamination. In deep water the presence of reducing salts of iron may convert nitrates into ammonia. Albuminoid ammonia may be either of animal or vegetable origin. As regards chemical standards for judging the wholesomeness of a water, the following points may be mentioned: (1) The water should be clear, free from colour, and show no deposit. Peaty water may be quite brown and yet wholesome, and well water may be bright and sparkling

and yet polluted. The physical characters are important, but are insufficient to condemn or pass the supply. (2) As a rule the proportion of solids should not exceed 50 or 60 parts per 100,000. The total hardness should not be above 30 parts per 100,000. (3) More than 2·5 parts of chlorine per 100,000 should arouse suspicion. (4) If there is practically no free ammonia, the albuminoid may considerably exceed 0·01 part per 100,000, and is then mainly of vegetable origin. If the albuminoid exceeds 0·005 part per 100,000, the free should not be above this amount. (5) In surface water the nitrates should not exceed 0·1 part per 100,000, and the presence of nitrites should condemn the water, as it shows pollution not yet completely oxidized. In deep waters considerable amounts of nitrates may be present, and yet the water be quite safe. Nitrates in the absence of ammonia are indicative of remote contamination.

There should not be more than 0·04 grain of lead or copper, 0·25 grain of zinc, or 0·5 grain of iron to the gallon in any water, and the faintest trace of arsenic should condemn.

A **bacteriological examination** usually aims at the discovery of evidence of sewage pollution, the *Bacillus coli communis* being taken as the indicator of this condition. Pure upland water contains no *B. coli*, but in inhabited districts *B. coli* derived from the intestines of human beings and lower animals gains access to the streams and wells. It is the *B. coli* of human origin that is significant, since it may be accompanied by such pathogenic human bacteria as the *B. typhosus*, *V. choleræ*, *B. dysenteriæ*, etc. There is no bacteriological method of distinguishing between the *B. coli* of human and animal origin. An inspection of the collecting area usually helps to determine the probable origin of *B. coli* found in a water. Surface-water supplies of large towns should not contain *B. coli* in smaller amounts of water than 10 c.c.; surface wells in the country usually contain the bacillus in much smaller quantities, but a well containing a typical *B. coli* in 1 c.c. should be condemned. Deep waters should contain no *B. coli*, even in 100 c.c. In determining whether filter-beds are working satisfactorily, an enumeration of the total number of bacteria capable of growing from 1 c.c. of the water when

planted on plates of nutrient agar and gelatine is usually undertaken. Filtered water should not contain more than 100 bacteria per c.c.

Where there is strong suspicion that a water is responsible for the transmission of typhoid fever and cholera, search by special cultural methods should be undertaken to detect their presence; but as a rule in the routine examination of a water pathogenic bacteria are not looked for. No significance is to be attached to a negative result in such a search, since (1) the long incubation period of typhoid allows of the disappearance of the bacilli from the water, and (2) the task is attended with great difficulties.

CHAPTER VIII

FOOD

The hygienic importance of a suitable dietary can be appreciated when it is realized that living beings are dependent upon food for the growth and repair of their tissues and for their supply of energy.

Classification of Foodstuffs.—In addition to inorganic and organic salts and water, the proximate principles of food consist of proteins, fats, and carbohydrates.

Proteins are the source of supply of the body's nitrogen, and are therefore especially necessary for the growth of the tissues of the child, as well as for the repair of the loss occurring during activity of the organs. Protein contains in general 16 per cent. of nitrogen, 54 per cent. of carbon, 22 per cent. of oxygen, 7 per cent. of hydrogen, and about 1 per cent. of sulphur. The ingestion of protein is soon followed by the excretion of a corresponding amount of nitrogen mainly in the form of urea. It would appear that only a fraction of the protein of the diet is required to repair tissue loss, and that the amido-acids into which the protein molecules have been converted in the process of digestion are absorbed, and after passage through the liver are directly excreted by the kidneys. It is certain that an excess of protein in the diet strains both liver and kidneys. The oxidation of the non-nitrogenous portion of the protein molecule results in the supply of heat and energy. Muscular exertion leads to great increase in the amount of carbon dioxide excreted, but to little or no increase of urea. The source of muscular energy apparently lies in carbohydrates and fat.

Carbohydrates, with the exception of lactose, or milk-sugar, are mainly of vegetable origin. In addition to six atoms of carbon, they contain hydrogen and oxygen in the proportions

in which these occur in water. Monosaccharides are aldehydes of hexatomic alcohols, and of these glucose, or grape-sugar, is a well-known example. Disaccharides are formed by the reunion of two molecules of a monosaccharide with the loss of water—*e.g.*:

$$\underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Lævulose.}}{C_6H_{12}O_6} = \underset{\text{Cane-sugar.}}{C_{12}H_{22}O_{11}} + H_2O.$$

$$\underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Dextrose.}}{C_6H_{12}O_6} = \underset{\text{Maltose.}}{C_{12}H_{22}O_{11}} + H_2O.$$

$$\underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Galactose.}}{C_6H_{12}O_6} = \underset{\text{Lactose.}}{C_{12}H_{22}O_{11}} + H_2O.$$

In the polysaccharides represented by starch and dextrin a large number of monosaccharide molecules are connected together—*e.g.*, $(C_6H_{10}O_5)n$ = starch.

Fats are combinations of a trivalent alcohol glycerine with three molecules of monobasic acids, principally stearic, palmitic, and oleic. Like the carbohydrates, they contain no nitrogen, but only carbon, hydrogen, and oxygen, and the proportion of the last element is insufficient to combine with all the hydrogen present to form water.

Fats and carbohydrates are the body's great furnishers of heat and energy. Carbohydrates enter largely into the dietaries of nearly all peoples, being cheap and easily assimilated, but they cannot entirely replace fat in the diet without injury to health resulting. On the other hand, where a supply of carbohydrate is not available—*e.g.*, among Esquimaux—health can be maintained on a diet consisting of protein, fat, and salts alone. However, when they have an opportunity, men instinctively partake of a diet containing all three proximate principles.

Salts enter largely into the chemical constitution of the body, and to replace those that are excreted a supply must be furnished in the food. In the colloidal mass composing the animal body electrolytes have an important rôle to play. Sodium chloride serves to keep the globulins in solution, and is the source of the hydrochloric acid of the stomach. Calcium salts, especially the phosphates, are necessary for cell growth and bone formation. Into the fluid tissues sodium, and into the solid tissues potassium, largely enter. Iron is an essential element in the composition of hæmoglobin. Salts of the organic

acids (lactic, tartaric, citric, malic, acetic) are oxidized into carbonates, and are important in maintaining the alkalinity of the blood. Vitamines are substances which are present in fresh foods in small amounts, and which are necessary for normal metabolism and growth.

Water composes two-thirds of the body's weight, and since the daily loss by the skin, lungs, and kidneys is great, a corresponding amount must be taken in the food. The evaporation of the water of perspiration is important in regulating the body temperature.

Nutritive Value of Foodstuffs.—Food is the source of the body's energy. Energy can be measured in terms of heat units. It is possible to convert the energy possessed by any body in motion into heat—*e.g.*, when a cannon-ball thrown from a high tower strikes the ground, the energy of movement is converted into heat. The potential energy contained in any food can be determined by ascertaining the amount of heat produced by its complete combustion in a calorimeter. Heat is measured in calories. A calorie is the amount of heat required to raise 1 gramme of water 1° C. The large calorie, which is the one always meant in expressing the nutritive value of food, is 1,000 small calories, or the amount of heat required to raise 1 litre of water 1° C.

In the body the combustion of carbohydrates and fat is complete, but protein is not completely oxidized, being largely excreted as urea, a substance which on combustion yields a considerable amount of heat. Making allowance for incompletely oxidized products, Rubner estimates that the combustion of 1 gramme of protein and of carbohydrate in each case yields 4·1 calories, whereas that of 1 gramme of fat yields 9·3 calories. Probably an addition of 10 per cent. to a dietary is sufficient to compensate for the portions that are unabsorbed from the intestine, and that are incompletely metabolized. It has to be borne in mind that the energy contained in a food is only available after its digestion and absorption, so that readiness and completeness of assimilation are important considerations with regard to a particular article of diet.

It has been found by Rubner that the amount of energy expended by a man at rest in the form of heat and of internal

work of the various systems is 2,500 caloiies. When the percentage composition of any food as regards protein, fat, and carbohydrate is known, it is easy to find the number of calories a certain quantity of that food would yield. To convert grammes to ounces, it is necessary to multiply by 28·34. One ounce of protein or carbohydrate yields $28{\cdot}34 \times 4{\cdot}1 = 116$ calories. The same amount of energy would be yielded by 12·47 grammes or 0·44 ounce of fat; in other words, 1 ounce of protein, 1 ounce of carbohydrate, and 0·44 ounce of fat are isodynamic.

A properly constituted diet should yield sufficient energy for the work required to be done by those consuming it. Voit's diet for a man doing hard muscular work, and the potential energy contained in it, are represented in the following table:

		Calories.
105 grammes of assimilated protein	×4·1=	430
56 grammes of fat	×9·3=	520
500 grammes of carbohydrate	×4·1=	2,050
		3,000

For severe exertion this diet is probably insufficient. Recently, with a view to the determination of a scale of field service rations, two experimental marches were carried out under the direction of the British Army Medical Advisory Board. In the case of one body of men the energy-value of the ration was 3,465 calories gross; in the case of the other, 4,511. The men with the lower scale of dietary lost weight, whereas with the more liberal scale there was a slight gain, and the men looked to be in far better condition. As a result of the experiment, the Army Council has approved of the raising of the field-service ration so that in future it will be 3 pounds in weight and represent 4,500 calories.

Relation between Heat and Work.—Energy is the capacity of doing work. The energy required to heat 1 gramme of water 1° C. would raise a weight of 425·5 grammes to a height of 1 metre; or 425·5 grammes of water falling through 1 metre would raise the temperature of 1 gramme of water 1° C. The mechanical equivalent of the calorie in terms of gramme-metres and foot-pounds is obtained by multiplying the calorie by

425·5 and 3,077 respectively. The mechanical energy of 1 gramme of each of the proximate food principles is as follows:

		Kilogramme-metres.
Protein	$4·124 \times 425·5 =$	1,754
Fat	$9·321 \times 425·5 =$	3,966
Carbohydrates	$4·116 \times 425·5 =$	1,751

The mechanical energy contained in Voit's diet, therefore, is—

		Kilogramme-metres.
Protein	$105 \times 1{,}754 =$	184,170
Fats	$56 \times 3{,}966 =$	222,096
Carbohydrates	$500 \times 1{,}751 =$	875,500
		1,281,766

In other words, the mechanical energy available from such a diet is about a million and a quarter kilogramme-metres, or nine million foot-pounds. Under ordinary circumstances a man transforms less than one-sixth of the available energy of his food into work, the rest being lost in the form of heat.

With the object of establishing a physiological dietary, determinations have been made of the daily loss of carbon and nitrogen. A man of 70 kilogrammes, or 11 stones, excretes each day, on an average, 20 grammes of nitrogen and 300 grammes of carbon. It has been found that nitrogenous equilibrium can be maintained with very varying amounts of protein. Chittenden, from the results obtained from experiments in which men were fed on a diet containing little more than half the usual amount of protein, concludes that such a reduction of protein is advantageous both on the grounds of health and economy. What the relative proportions of the proximate principles should be is still a matter of opinion, but probably in the best diets the proportion of protein to carbohydrate is 1 to 5, and of fat to carbohydrate 1 to 8.

An essential in any scale of rations is variety. There is the greatest difference in the diets of different nations, and it is possible that the low nitrogenous fare of the Bengali and the rich protein diet of the beef-eating Britisher may have had an important effect in the production of their national characteristics.

Calculation of Diets.—A workman is supplied with a diet consisting of 9 ounces of meat, 18 ounces of bread, 16 ounces of potatoes, 16 ounces of milk, 2 ounces of butter, and 3 ounces of oatmeal. To calculate the amount of the proximate principles and of the energy contained in it, the first essential is a table showing the composition of the various ingredients—*e.g.* :

	In 100 parts.			
	Proteins.	Fats.	Carbohydrates.	Salts.
Raw meat	20·5	8·5	—	1·5
Hen's eggs	13·5	11·5	—	1·0
Cow's milk	4·0	3·5	4·5	0·7
Butter	1·5	83·5	1·0	1·5
Cheese	28·0	23·0	1·0	7·0
Bread	8·0	0·5	50·0	1·5
Potatoes	2·0	0·1	21·0	1·0
Oatmeal	12·6	5·5	63·0	3·0

By simple proportion, it is obvious that the amount of proximate principles from the above quantities is as follows:

	9 ozs. Meat.	18 ozs. Bread.	16 ozs. Potatoes.	16 ozs. Milk.	2 ozs. Butter.	3 ozs. Oatmeal.	Total.
Protein.. ..	1·845	1·44	0·320	0·64	0·03	0·378	4·653
Fat	0·605	0·09	0·016	0·56	1·67	0·160	3·101
Carbohydrate ..	—	9·00	3·360	0·72	0·02	1·990	14·090

The energy available is $4{\cdot}6 \times 4{\cdot}1 \times 28{\cdot}3 = 533$ calories furnished by protein; $3{\cdot}1 \times 9{\cdot}3 \times 28{\cdot}3 = 815$ calories furnished by fat; and $14 \times 4{\cdot}1 \times 28{\cdot}3 = 1{,}624$ calories furnished by carbohydrate, giving a grand total of 2,972 calories or practically 3,000 calories.

Diseased Conditions attributed to Diet.—It is not improbable that faulty dieting is responsible for much of the physical degeneration observed among the employés in factories and warehouses in large cities. Chronic underfeeding lowers the resisting powers of the tissues against bacterial invasion. It has been shown that a considerable number of the children attending school in England do not obtain sufficient food at home to enable them to be in a fit state to acquire instruction. There

are several morbid conditions in the etiology of which the diet is supposed to play a leading part. These are Rickets, Scurvy, Scurvy-Rickets or Barlow's Disease, Beri-Beri, and Pellagra.

Rickets is a condition occurring among young children in which the ossification of the bones proceeds in an irregular fashion, resulting in deformity of the skull and limbs. As a rule the child is anæmic, its abdomen is distended, and gastro-intestinal symptoms are present. The condition is due to improper feeding, the main mistake being the excessive consumption of carbohydrate, and the sparing use of fats and proteins.

Scurvy was once common among sailors. The symptoms are anæmia, spongy bleeding gums, hæmorrhages into various parts of the body, and wasting. The blood as a rule shows a decrease in its alkalinity, and some have attributed the condition to an acid intoxication. For the prevention and cure of scurvy fresh vegetables are useful. The benefit accruing from the use of vegetables has been attributed to their organic acids, which are oxidized in the body into carbonates. However, the disease may not appear when fresh vegetables are absent from the diet, as among Nansen's crew on his Polar expedition. It has been found that the essential cause of the disease is the consumption over prolonged periods of stale or preserved food. Fresh meat or fresh vegetables contain some element, which is essential for normal metabolism. Dried vegetables lose their antiscorbutic effect, although the mineral salts are still present in undiminished amount. The use of lime-juice, as in the Mercantile Marine, is useful prophylactic.

Scurvy-Rickets, or Barlow's Disease, occurs among young children, and presents a combined feature of Scurvy and Rickets. The use of skimmed, preserved, and stale milk is a factor in its causation.

Beri-Beri.—The essential lesion in this disease is a peripheral Neuritis, leading to Muscular Paralysis and to irregular action of the heart when the cardiac nerves are involved. Œdema of the skin and effusion into serous cavities may be present in the moist variety. The disease prevailed amongst the underfed part of the populations of the Malay Archipelago, the Philippines, and in China and Japan. Ship Beri-Beri occasion-

ally breaks out on sailing-ships, where the diet has been deficient in amount or quality. Some idea of the extent of this scourge in the tropics may be imagined when it is stated that in the Federated Malay States (population, 1,036,999 in 1911) 45,000 deaths from Beri-Beri occurred in the course of thirty years. Takaki, in 1884, believing the disease to be the result of nitrogen-starvation, was able to eradicate it from the Japanese Navy (in which one-quarter of the personnel was constantly down with the disease) by giving a diet richer in protein. The view that in the East the prevalence of the disease is due to the consumption of "milled rice"—*i.e.*, rice which has been polished by the removal of its outer layer, or pericarp—has been confirmed. By abolishing the use of milled rice in the Philippines, the Americans have succeeded in stamping out the disease in those islands.

Fowls develop Polyneuritis when fed on polished rice, and this can be cured by the administration of the "polishings," or rice-bran. Funk has been able to isolate the active principle, and to it he has given the name "vitamine." About 10 grains of this crystalline substance are contained in 1 ton of rice. The administration of minute quantities of this substance is able to cure and prevent Beri-Beri in fowls. Vitamine has also been found in yeast, fresh limes, and it or allied substances are necessary to prevent Scurvy, Rickets, and possibly Pellagra. The discovery of vitamines has shown how metabolism may be affected by the absence of certain essential comparatively simple compounds. When the diet is abundant and varied, Beri-Beri is unlikely to develop, but in the diet of underfed coolies and sailors vitamine may be absent, and the disease result.

The preventive measures are the substitution of unpolished rice for the polished grain, and the addition of barley and rice-bran to the diet.

Pellagra.—The chief symptoms of this disease are an erythematous dermatitis of the skin of exposed parts of the body, digestive disturbances, cachexia, and degenerative changes in the nervous system, ending eventually in delusional insanity. The disease has recently been recognized in these islands, and prevails widely in Southern Europe and parts of America. Until

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PLATE VIII.

FIG. 19.—Slaughter Hall: Belfast Municipal Abattoir.

The animals are slaughtered out of sight of each other in recesses at the side. The carcasses suspended from wheels on runs overhead are readily transported to cooling shed.

quite recently the view that the disease was due to the consumption of spoiled maize was generally accepted. In the fermentation of the maize it was thought that toxins were generated which, when ingested for long periods, produced the symptoms. Sambon has shown the inadequacy of the maize theory to explain the geographical distribution of Pellagra, and has suggested that it should be attributed to a protozoon parasite conveyed by Simulium, a species of midge. So far, Sambon has adduced in support of his theory evidence of an epidemiological rather than of an experimental nature.

Meat.—The flesh of a great number of animals is used as food. Meat contains much protein and fat, but little carbohydrate. The relative amounts of protein and fat vary in different animals and in different parts of the same carcass. On an average, 75 per cent. of the meat consists of water. In fat meat the proportion of water is less. In beef there is on an average 20 per cent. of protein. During the state of rigor mortis the carcass should be kept in a cooling shed, and used only after rigor mortis has passed off, since at this stage the meat is more tender. From meat can be extracted mineral salts, chiefly phosphate of potassium and crystalline nitrogenous substances—*e.g.*, creatin, creatinine. These are the chief constituents of beef-tea, which act as stimulants and assist in the digestion and absorption of other food. Since many diseased conditions are due to morbid states of meat, it is necessary in the interests of public health that there should be strict inspection of all meat intended for human consumption. Imported meat is inspected at the ports by special meat inspectors acting under the Medical Officer of Health. Sanitary inspectors are required to inspect private slaughter-houses, but it has been found in practice that supervision can only be properly exercised when public abattoirs are provided by the Sanitary Authority, and when all butchers are compelled to slaughter their animals under the eyes of the meat inspectors. At a public abattoir the animal can be inspected before slaughter, and all the viscera are retained for examination. In a private slaughter-house the butcher can cut away diseased portions of the meat, and sell the remainder as sound, since the inspector rarely is present at the moment of slaughter.

Meat should be firm and elastic, and not œdematous. There should be no hæmorrhages in its substance, as these are indicative of acute disease. No disagreeable odour should be imparted to a skewer thrust down to the bone. The bone-marrow should be of a rosy red colour. Commencing putrefaction is indicated by the flesh becoming pale and of an offensive odour. Later a greenish colour develops. The flesh should be free from pathogenic bacteria and animal parasites. The flesh of animals suffering from Septicæmia, Anthrax, Glanders, and generalized Tuberculosis should be condemned. If cysticerci of the *Tœnia solium* or *T. saginata*, or the embryos of the *Trichina spiralis* are found, the whole carcass is destroyed. Liver flukes necessitate the destruction of the affected organ only unless the animal is extremely emaciated. The age of an animal affects the character of the meat; oxen five or six years of age afford the best meat. The flesh of old animals is tough and the fat often yellow. The flesh of animals suffering from Pleuro-Pneumonia and from Foot-and-Mouth disease should not be consumed. With regard to Tuberculosis, a Royal Commission in 1898 advised that the entire carcass and all organs should be seized in cases of—

1. Miliary Tuberculosis of both lungs.
2. Tuberculous lesions on the pleura and peritoneum.
3. Tuberculous lesions in muscle or intermuscular lymphatic glands.
4. Tuberculous lesions in any part of the emaciated carcass.

Only the affected parts are to be seized when the lesions are confined to (*a*) the lungs and thoracic lymphatic glands; (*b*) the liver; (*c*) the pharyngeal lymphatic glands; (*d*) any combination of the foregoing, if the lesions are collectively small in extent. Foreign meat with "stripped" pleura should be condemned. It was also recommended that, "in view of the greater tendency to generalization of Tuberculosis in the pig, the presence of tubercular deposit in any degree should involve seizure of the whole carcass and of the organs." Few sanitary authorities have been able to carry out this last recommendation.

In certain cases the flesh of animals having tubercular deposits on the pleura and peritoneum appears sound, and in such cases the German custom of removing the deposits, cooking

the flesh so as to sterilize it, and selling it at a cheap rate, is worthy of imitation in this country.

Food-Poisoning.—Meat that has undergone decomposition may on ingestion, in virtue of the ptomaines contained in it, give rise to gastro-intestinal disturbance. As a rule the unpleasant taste prevents much of such food being partaken of. It is very different in cases of true food-poisoning, where definite pathogenic bacteria are concerned—*e.g.*, *Bacillus botulinus* and *B. enteritidis of Gaertner*.

The *B. botulinus* is an anaërobe which is able to produce in ham, sausages, and other flesh foods, a powerful toxin, without in any way affecting the taste or appearance of the food. The toxin has a great affinity for the medulla oblongata and the centres of the special senses. Paralysis of the tongue and pharynx, dilatation of the pupil, and aphonia, occur twelve to twenty-four hours after the poisonous food has been taken. The toxin is a toxalbumin, and is destroyed by boiling. Botulismus (the name given to this condition) is of rare occurrence.

The *B. enteritidis* (*Gaertner*), or some closely allied species, is responsible for the majority of food-poisoning outbreaks. These bacilli produce a toxin which is resistant to the action of heat, and which causes Vomiting, Diarrhœa, and profound collapse, sometimes terminating fatally. In certain cases infection with the bacillus results, and the disease produced resembles Typhoid Fever. The meat usually presents nothing abnormal in its appearance, and the manner in which it becomes affected is doubtful. In some instances the animal has presented signs of illness before being slaughtered, and in such cases the bacilli are derived directly from the multiplication of those with which it has been infected. In many outbreaks the source of infection was not with certainty ascertained, but was thought to be due to storage of the meat in insanitary places.

Preservation of Meat.—Partial or complete desiccation, brought about by exposure to the sun or to fires, inhibits the growth of putrefactive bacteria. Instances of these processes are seen in the preparation of the *carne secca* of the South Americans, and of pemmican of the North American Indians, and of the smoked bacon of Limerick. Salt has been used

since time immemorial as a preservative, and is the one chemical reagent which can be used for this purpose with safety. The use of boracic acid, salicylic acid, sodium sulphite, and formaldehyde, is objectionable, as these substances harden the fibres and interfere with normal digestion. The meat can be smeared over the surface with salt, or can be pickled in brine.

The effect of cold in preventing bacterial growth is now extensively used, not only for shipping meat long distances, but also for preserving the meat in the butcher's shop. The meat may be frozen, or a better plan is to keep it at a little above 0° C., since this does not produce laking of the hæmoglobin and staining. Frozen or chilled meat does not keep long after being brought to the temperature of the air. Refrigerating plant forms part of the equipment of a large public abattoir.

Sterilization by heat as a method of preserving food was introduced by Appert over a century ago. Its application is seen in the canning of meat. The meat is sealed up in tins, which are placed in steam under pressure at 115° C. for one or two hours. The contents of the tins expand and cause bulging. One end is therefore punctured to allow air to escape, and then the opening is immediately soldered up again. The tin is heated for another hour to complete the sterilization. The escape of the air creates a partial vacuum in the tins, so that their tops and bottoms are slightly depressed. If gases resulting from putrefaction develop, the ends bulge, and the tins are said to be "blown." Spore-forming bacteria may have escaped destruction, and these are especially liable to develop and produce gas if the tins are exposed to tropical heat. To test the tins, it is therefore advisable to incubate specimens at a temperature of 37° C. The contents of the tins should be firm, the gelatine being in a solid state, and the tin should be bright and show no evidence of blackening from action of sulphuretted hydrogen formed prior or subsequent to sterilization. The tin in which food is preserved should not contain more than 1 per cent. of lead.

A few remarks about the cooking of food may be made at this point. **Cooking** (1) coagulates the proteins, (2) gelatinizes the connective tissue, (3) facilitates mastication,

(4) renders the food more palatable, and in consequence promotes digestion, (5) destroys animal and vegetable parasites. When it is desired to retain extractives within the substance of the meat, the latter should be exposed to a temperature of 100° C. for a short time, so as to coagulate completely the albumin on the surface; afterwards the cooking should continue at a temperature of about 70° C. Fish is nutritious, and might with advantage enter more largely into the diet of people who find other protein foods expensive.

Oysters contain 6 per cent. of albuminous material, and are readily digested. The objection to the use of oysters is the fact that they are often grown in polluted areas, and so may become the medium for conveying such diseases as Typhoid Fever. A classical example of oysters being responsible for an outbreak of Enteric Fever was the occurrence at the Mayoral Banquets held on the same day in Winchester and Southampton in the year 1902. At both banquets oysters from the same source were consumed, and over 40 per cent. of the guests suffered from gastro-intestinal symptoms. Not all of the guests partook of the oysters, but all who developed Enteric Fever had done so.

Mussels occasionally contain an alkaloid mytilotoxin, which has in some instances caused death. Mussels and cockles collected from polluted foreshores are fruitful agencies in the dissemination of Typhoid Fever. Dr. Darra Mair, after an extensive investigation, concluded that the consumption of shellfish was mainly responsible for the Typhoid Fever which was at one time prevalent in Belfast. Since the sale of such shellfish has been prohibited by the Sanitary Authority, the Typhoid Fever incidence-rate has markedly declined.

Eggs contain protein and fat in a readily assimilable form. A hen's egg weighs 2 ounces. The white consists mainly of albumin, and the yolk of fat and nucleo-albumin. Of the whole egg, about 74 per cent. is water, 14 per cent. protein, 11 per cent. fat, and 0·8 per cent. salts. In a solution of 2 ounces of salt in a pint of water good eggs will sink, and stale ones float. Eggs can be preserved by the exclusion of air from their interior by means of coatings of silica, or water-glass.

Milk is Nature's food for the young mammal. The mother's milk belongs to the child, and only in exceptional circumstances should be withheld. There are distinct chemical and biochemical differences between the milks of different species of animals; there are also individual variations.

On an average, 87 per cent. of milk consists of water. In human milk, the milk-sugar amounts to over 6 per cent., whilst cow's milk contains about 4·5 per cent. As regards fat in human milk there is 3 per cent., and a poor specimen of cow's milk should contain as much. The proteins of cow's milk consist mainly of casein, and are present to the extent of 3·5 per cent.; in human milk the proteins are half this amount, and consist mainly of milk-albumin. The salts in human and cow's milk are respectively 0·3 and 0·7 per cent. Milk therefore contains all the proximate food principles, and is an ideal food for infants and the sick. It is not sufficiently concentrated for adults, but forms an important constituent of any dietary. Condensed milk is prepared by evaporating milk down to one-third its bulk, and then adding sugar. Dried casein is the chief constituent of such dietetic preparations as plasmon, nutrose, etc. Milk is frequently fraudulently altered in its composition, the chief adulteration being the abstraction of cream and the addition of water. There is strong presumption that a milk sample is not genuine if it contains less than 3 per cent. fat and less than 8·5 per cent. of "solids-not-fat." The addition to milk of preservatives is forbidden. The chief preservatives which have been employed are boracic acid, formaldehyde, salicylic acid, and fluorides. These substances interfere with digestion, and allow of stale milk being placed on the market.

Milk serves as a favourable medium for the growth of many saprophytic and pathogenic bacteria. Milk, as it leaves the teat, contains no bacteria except a few streptococci, which grow in the milk canaliculi; but as commonly supplied to the householder, it contains several million bacteria per cubic centimetre—in fact, its bacterial content is richer than that of sewage. These bacteria are derived from the contamination of the milk by fæcal matter from the cow, from dust, from use of unclean utensils, etc. If the cow is suffering from an

infective disease, the virus may be excreted in the milk, as in the case of Foot-and-Mouth Disease and Tuberculosis. Tubercle bacilli are found in milk not only when there is a tubercular deposit in the udder, but also when bacilli are being excreted by the intestinal tract. Some American cities have attempted to frame standards with reference to bacteria in milk. A standard commonly adopted is that the number of bacteria should not exceed 500,000 per c.c.

Milk acts frequently as the vehicle for the transmission of disease. Examples of diseases transmitted to man by milk are Tuberculosis, Typhoid Fever, Diarrhœa, Cholera, Diphtheria, Sore Throat, Scarlet Fever, Malta Fever, and Foot-and-Mouth Disease.

In a considerable proportion of the tubercular lesions of children, bacilli of the bovine type are the infecting agents. The Royal Commission on Tuberculosis, reporting in 1907, states that "a very considerable amount of disease and loss of life, especially among the young, must be attributed to the consumption of cow's milk containing tubercle bacilli."

The prevention of this result can be effected in two ways: (1) The supply of milk free from tubercle bacilli; (2) the supply of pasteurized milk.

The first method is radical, but it will require some years to be carried into effect. The attainment will involve—(1) The breeding of cattle from animals which do not react to tuberculin (if the mother reacts, the calf must be isolated); (2) the segregation and eventually slaughter of reacting animals; (3) improvement of byres, etc. The expense entailed will be considerable, but the ideal to aim at in this, as in water-supplies, is to insure purity at the source.

The object of the **pasteurization** of milk is to destroy any pathogenic bacteria which may be present. Pasteur introduced the method of heating wine to a temperature not exceeding 70° to 75° C., and the same process has been applied to milk. In both the wine and the dairy industries this treatment destroys acid-producing bacilli. The majority of pathogenic bacteria are killed by exposure for twenty minutes to 75° C. Spore-forming bacteria survive, and if the milk is kept, may develop and form harmful products, the lactic acid

bacilli which usually inhibit their development having been destroyed by the pasteurization. The milk should be contained in a bottle placed in a water-bath, which is provided with a lid. The heating process should be immediately followed by cooling to a temperature unfavourable to the growth of bacteria which have escaped destruction. The disadvantage of pasteurization is that there is a slight change in the casein and albumin, and some loss of lecithin. The advantages are very considerable: (1) The casein is more easily digested; (2) pathogenic germs are destroyed; (3) in the immense majority of cases the use of pasteurized milk has been attended with excellent results in the rearing of children. The giving of a little meat or fruit-juice removes any danger of the development of Scurvy-Rickets.

Typhoid and diphtheria bacilli rapidly multiply in milk without altering its appearance. Many epidemics of these diseases have been traced to milk infected from a human source. The occurrence of several cases of these diseases among people having the same milk-supply should always arouse the suspicion of the Sanitary Authority with regard to the milk. Milk epidemics are explosive in character, and often the cases are most abundant among the well-to-do, who consume most milk. In the Report of the Irish Local Government Board for 1911 an account is given by Dr. Brian O'Brien of an outbreak of milk-borne Typhoid Fever which occurred at Donacloney, Co. Down, in which the bacilli gained access to the milk from a servant-girl, who was found by Professor McWeeney and the writer to be a chronic intestinal typhoid "carrier." The chief facts of the epidemic are contained in the following brief account:

In a village having a population of 755, and 130 houses, there were 36 cases of Enteric Fever notified within six weeks in the spring of 1911. The milk-supply was promptly stopped by the medical officer of health after the second notification, the patient in this case being the man who delivered the milk. This man and his employer, the dairyman, both died from the disease. The source of infection proved to be a dairymaid, who had had an attack of Typhoid Fever in 1908, and who had been herself infected by a "carrier." This dairymaid entered service at the farm in the middle of November, 1910.

Her previous employer contracted Typhoid Fever during her sojourn at his house. The suspected milk was supplied to 66 houses, with an aggregate number of inmates of 355. Twenty-four houses were infected, and there were 36 cases of enteric fever, giving a morbidity-rate of 10·1 per cent. No case occurred among the 400 people who did not obtain milk from the suspected dairy.

In several outbreaks of Diphtheria virulent Klebs-Loeffler bacilli have been isolated from the suspected milk, but in the majority of cases the main incriminating evidence has been the discovery of a "carrier" at the dairy.

That Scarlet Fever may be milk-borne is open to no doubt, but whether the infectivity is always acquired from a human source has been questioned. In several outbreaks, notably that occurring at Hendon in 1885, there was a suspicion that the milk might have acquired its virus from the cow. Further evidence is necessary to prove that cows suffer from a modified form of Scarlet Fever, and are capable of infecting human beings who consume their milk. It is probable that milk-borne epidemics of Sore-Throat illness are due to streptococci derived from cows suffering from Mastitis. In the dissemination of Cholera and Epidemic Diarrhœa milk is one of the most important agents. In Malta Fever, goat's milk is the chief source of human infection.

Ice-Cream has on several occasions been responsible for outbreaks of Typhoid Fever. Bacteria that have gained access to the cream before it is frozen multiply, and the subsequent freezing does not kill them. All foods into which milk enters should be prepared under the most scrupulous hygienic conditions.

Butter consists of the fat of milk, and should not contain more than 16 per cent. of water. About 8 per cent. of butter fat is composed of butyrin, caproin, and caprylin, the acids entering into these fats being volatile. The presence of these volatile fatty acids is characteristic of butter, and is the chief difference between it and **Margarine,** which consists mainly of olein, stearin, and palmitin, derived chiefly from animal fat. The nutritive value of margarine is probably as high as that of butter.

Cheese consists of coagulated casein, with amounts of fat which vary according to whether it has been prepared from whole or skim milk, or from milk to which extra cream has been added. Good cheese usually contains twice as much nitrogen and three times as much fat as the same weight of meat. On an average, cheese contains 20 to 35 per cent. of water, and 3 to 6 per cent. of salts. The remainder consists mainly of casein and fat, and the proportion of fat to casein should not be less than 1 to 2.

Vegetable Foods.—The general characters of these foods are—(1) Richness in carbohydrates. The amount present in most cereals is 70 per cent. (2) Deficiency in fat. Exceptions to this rule are furnished by nuts, almonds, olives, etc. Oats contain 5 per cent. of fat. (3) Protein present in the form of globulins and albumoses—*e.g.*, glutin, legumin—which are formed from globulin and albumose by the action of water. (4) Richness in salts and organic acids. (5) The possession by the vegetable cells of membranes composed of cellulose, a substance which is indigestible, but which promotes intestinal peristalsis.

The **Cereals**—wheat, rye, barley, oats—contain on an average 10 to 12 per cent. of protein, and 65 to 75 per cent. of carbohydrates. The percentage of fat and mineral matter seldom exceeds two in each case. The grain of wheat consists of—(1) the germ, or embryo plant; (2) the kernel, or endosperm, representing 85 per cent. of the grain, and consisting of starch and protein; (3) the bran, or outer envelope, consisting mainly of cellulose. In the old method of stone-grinding, the bran was removed and the germ was left attached to the endosperm. In modern roller-milling, the endosperm and germ are separated. The germ is rich in nitrogenous matter and fat, so that its removal lessens the nutritive value of the flour. The retention of the germ is liable to lead to the spoiling of the flour through its oil becoming rancid, and the bread baked from such flour becomes dark in colour through the action upon the starch of ferments contained in the soluble proteins of the germ. Treatment of the germ with superheated steam prevents these objectionable results by sterilizing the oil and destroying the ferments. The germ so treated is ground to a fine meal, and

of this 1 part is added to 3 of ordinary flour, the mixture constituting "Hovis" flour.

The starch-grains of the various cereals present characteristic appearances under the microscope, which can be used to detect admixture.

If flour is mixed with water and baked, ship's biscuit is produced. To obtain a product of less flinty consistence it is necessary to permeate with gas the dough during the baking process. It is only from flour containing gluten that bread can be prepared. The viscid character of gluten enables it to remain spongy when blown up with gas. The gas employed is carbonic acid generated by the use of yeast or baking-powders in the dough. In the making of aërated bread, the carbonic acid is prepared apart from the dough, and is then forced into the latter under pressure. Yeast causes fermentation of the starch, producing, first, sugar, and then breaking the latter up into carbonic acid gas and alcohol, which escape from the bread during the latter stage of the baking.

Baking-powders consist essentially of sodium bicarbonate, together with an acid substance (cream of tartar, tartaric acid, calcium acid phosphate, etc.), which will liberate carbon dioxide from it when water is added, and so cause "rising" of the bread or pastry. Calcium acid phosphate is often adulterated with calcium sulphate, an inert and undesirable ingredient.

Wheat flour is frequently bleached in order to produce a very white bread. Bleaching enables a lower-grade flour to simulate the appearance of an unbleached higher grade. Nitrogen peroxide is used for the purpose, and as a result, nitrites are found in the flour. Nitrites have an inhibiting action on digestion. Alum is sometimes added to bread to improve its colour, but the practice should be prevented, since alum unites with the phosphates of the flour, rendering them insoluble, and preventing their absorption.

Macaroni and **Vermicelli** are prepared from flours rich in gluten. They are highly nutritious food.

The **Pulses** comprise peas, beans, lentils, and their allies. They are exceedingly rich in nitrogen, and are a valuable and cheap source of protein, pea flour containing 28 per cent. of

this substance. They are somewhat difficult to digest. Potatoes are poor in protein, rich in starch and antiscorbutic substances.

Tapioca, Sago, and **Arrowroot** consist almost entirely of starch. Tapioca is prepared from the roots of the Brazilian cassava-plants, sago from the pith of the sago-palm, and arrowroot from the rhizome of a West Indian plant, *Maranta arundinacea.*

Cabbage and other green vegetables are valuable on account of the organic acids contained in them. **Fruits** are important for the same reason, as well as for their agreeable flavour and their stimulating action upon the bowel. Nuts possess a high nutritive value, containing often 50 to 60 per cent. of fat, 15 to 20 per cent. of protein, and 9 to 12 per cent. of carbohydrates.

Sugar, or saccharose, is derived from the sugar-cane, sugar-beet, and sugar-maple. It is a source of much energy, and, being practically pure carbohydrate, every gramme of it yields 4·1 calories. An ordinary lump of sugar weighs 5 grammes, and yields therefore fully 20 calories. That the use of sugar lessens fatigue has been proved by experimental marches. It is a valuable food for the muscular system, including the heart. It is the basis of all sweetmeats, and is the preservative agent in jams. Glucose is sometimes substituted for cane-sugar in the preparation of these substances. Spices and condiments are not absolutely necessary, but their use improves the appetite and digestive powers. Examples are mustard, pepper, vinegar, ginger, cinnamon, cloves, and allspice.

Beverages.—Tea consists of the dried leaves of the tea-plant. The varieties of tea are named according to the different leaves from which they are produced, the smaller leaves being most highly valued. The chief difference between black and green tea is that the former is fermented, and its infusion contains less tannic acid. Black tea contains about 3 per cent. of the alkaloid caffeine. If tea be infused in the usual way, about 25 per cent. of the leaf goes into solution. A teacupful of tea of ordinary strength infused for five minutes contains about 1 grain of caffeine and two or three times as much tannic acid.

Coffee is the seed of the *Caffœa arabica*. The beverage is prepared after the seeds have been roasted and ground. From 1 to 2 grains of caffeine are present in a cup of coffee.

Cocoa is prepared from the roasted seeds of the *Theobroma cacao* by grinding the substance left after expression of the fat. The chief alkaloid in cocoa is theobromine, which is closely related to caffeine, the latter being methyl-theobromine.

Chocolate consists of ground cocoa, from which the fat has not been removed, mixed with sugar, starch, and flavourings.

Tea and coffee are in no sense foods. They stimulate the nervous system, and diminish nervous fatigue. Excessive indulgence in these beverages is liable to produce sleeplessness, palpitation, nervousness, and digestive disturbance. Theoretically, cocoa is a valuable food, but since only a small portion of the solid cocoa is taken in each cup, the place of cocoa in the diet is not very different from that of tea and coffee.

Alcoholic Beverages.—The principal constituent of alcoholic drinks, and the one which is mainly responsible for their effect upon the body, is ethyl alcohol. This is produced by the fermentation of sugar contained in—(1) grape-juice, (2) wort prepared from malted grain, (3) various fruits, (4) glucose formed from the action of sulphuric acid upon starch. As regards the physiological action of alcohol, the following points have been determined: (1) When the dose does not exceed 1 ounce, the greater part of the alcohol is oxidized, and supplies heat and energy. One ounce is contained in 2 ounces of brandy, 5 ounces of the strong wines (20 per cent.), 10 ounces of the weak wines (10 per cent.), 20 ounces of beer (5 per cent.). The alcohol is rapidly absorbed and oxidized. (2) The flow of gastric juice and the movements of the stomach are augmented. The action of pepsin is not retarded until the proportion of alcohol in the stomach contents exceeds 5 per cent. (3) The force and frequency of the heart-beat are augmented, and the excess of blood sent to the brain probably accounts for the preliminary cerebral stimulation. (4) The superficial vessels of the body dilate, and (5) in consequence the temperature of the body is slightly depressed. (6) The brain cells are partially anæsthe-

tized. (7) The oxidation of alcohol in the body spares fat and carbohydrate, but it has no important power of diminishing nitrogenous waste.

The paralyzing effect of alcohol on the nervous system to a great extent annuls any useful effect that alcohol may as a food possess. Alcohol is essentially a stimulant, and in conditions where the heart is flagging, its judicious use is often attended with benefit. The abuse of alcohol is liable to produce gastritis, cirrhosis of the liver, neuritis, and degenerative changes in the brain.

Alcoholism is one of the greatest social evils, and is one of the most formidable obstacles to the progress of Hygiene. As a cause of crime, vice, poverty, insanity, moral and physical degeneration, the part played by alcohol is second to none. Beer, which is "a fermented saccharine infusion to which has been added any wholesome bitter," contains on an average per pint 1 fluid ounce of alcohol, $1\frac{1}{2}$ ounces sugary extract, 20 grains of free acid, and 14 grains of salts. A pint of good ale contains as much carbohydrates as $1\frac{1}{8}$ ounces of bread, and will yield about 337 calories of energy; and 2 pints will contain one-fifth of the total energy required daily. Formerly only hops were used to impart a bitter taste to beer, but now quassia, gentian, and calumba are frequently employed. In the preparation of beer there is, unless special precautions are taken, a risk of arsenic gaining access to the beverage from—(1) fumes from furnaces employed in drying the malt, (2) arsenic contained in the sulphuric acid employed in the preparation of artificial glucose. An outbreak of arsenical poisoning which occurred in the North of England in 1900 was traced to this cause. There were several thousand cases, and some samples of the beer contained $\frac{1}{4}$ to $\frac{1}{2}$ grain As_2O_3 per gallon. A Royal Commission on Arsenical Poisoning recommended a penal limit of $\frac{1}{100}$ grain of arsenic (As_2O_3) per pound or per gallon in any food-substance. The symptoms of Arsenical Poisoning include peripheral neuritis, pigmentary and other changes in the skin.

Artificial glucose is employed in the manufacture of jams, sweets, lemonade, so that here also precautions against Arsenical Poisoning must be taken.

It is the duty of the Sanitary Authority to see that the

alcoholic beverages sold in their district conform to the legal standards.

Aërated Waters.—Ordinary water, or water to which various chemical salts have been added, are impregnated with carbonic acid gas, and sold as soda-water, potash-water, lithia-water, etc. The basis of lemonade, ginger ale, etc., is water sweetened with cane-sugar, and rendered tart by the addition of an acid, and then flavoured in any desired way, and finally charged with carbonic acid gas. The best varieties in the British Isles come from Belfast. The water should be pure, and the bottles and stoppers should be thoroughly cleansed, and poisonous metals should be absent. Carbonic acid gas under pressure after a time destroys most micro-organisms present in water, but in all cases the water should be above suspicion. The majority of people find the use of mineral waters agreeable, and unattended with any harmful result, but people suffering from cyanosis and flatulence would probably do well to abstain.

CHAPTER IX

BUILDINGS

PROPER housing of the people is essential for the development of a healthy race. New houses are constructed under the supervision of the Sanitary Authority, and must comply with the sanitary requirements of the local by-laws. In all houses there should be provision for adequate ventilation and lighting, for the rapid removal of refuse and excreta from the premises, and for the prevention of dampness. With regard to all these points, the site of the building is an important consideration. The **site** should be dry and non-polluted; the level of the ground-water should be 5 to 15 feet from the surface, and it should not be subject to sudden fluctuations. A porous soil, such as gravel, is an ideal site, provided that—(1) the ground-water stands at a low level, (2) that the ground is not polluted with organic matter, since in such circumstances emanations would readily escape from it. Primitive rock and such strata as sandstone and limestone form excellent sites, being dry and warm. Clay, on account of its high percentage of moisture, is cold, but if it has a good fall for surface-water, is unobjectionable. In towns, hollows are often filled up with refuse from ashpits and from street-sweepings, and this "made soil," as it is termed, then serves as sites for houses. By the action of bacteria, of air, and rain, such sites are in time purified, but before being used care should be taken to see that the processes of putrefaction and fermentation, whereby the organic matter is destroyed, have come to an end. It has been found that after three years this process of purification is well advanced, though not quite complete. During this time such accumulations are apt to be a nuisance to the neighbourhood, serving as breeding-grounds for rats and flies, as well as sources of dust and offensive effluvia.

PLATE IX.

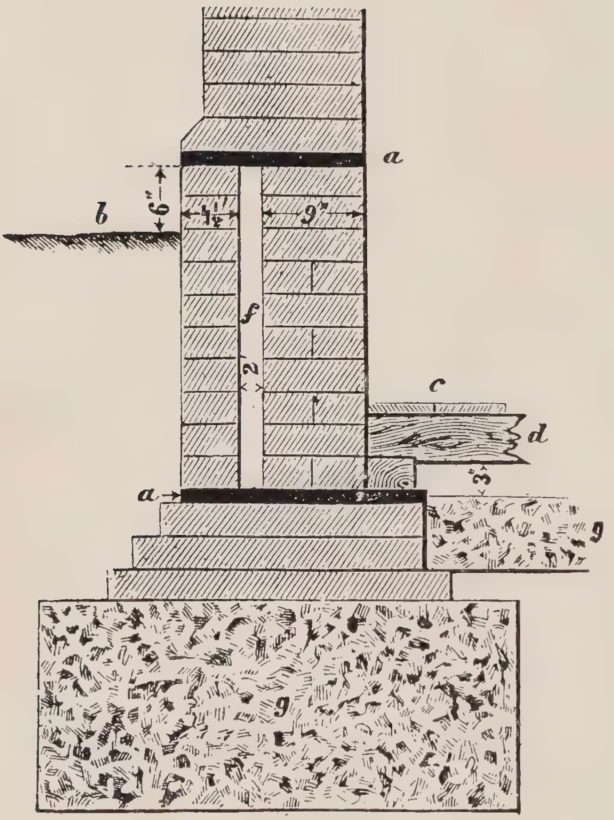

Fig. 20.—Position of damp-proof courses *a*, *a*, in wall of a building erected below level of adjoining ground ; *g*, *g*, layers of concrete ; *f*, dry area.

(*From* Knight's "Annotated Model By-Laws.")

In all cases it is an advantage to cover the entire site of a house with a layer of concrete 6 inches in depth. Concrete consists of 1 part of cement, 2 parts of sand, and 3 parts of ballast. Underneath the walls the concrete should be 12 inches in depth, and in this position at any rate this precaution against dampness should not be dispensed with even in those cases where it is found impracticable to cover the whole site. The walls of buildings are usually constructed of bricks, and as brick can absorb 16 ounces of water, it is necessary to prevent the passage of this moisture up the walls by the insertion of a damp-proof course 6 to 12 inches above the level of the ground and below the level of the joists supporting the floor. This **damp-proof course** may consist of a variety of material—*e.g.*, sheet-lead, slates embedded in cement, asphalt, glazed bricks, or tiles. The latter are often perforated, and then help to ventilate the space beneath the floor of the building. This space should be about 2 feet in depth, and there should be free ventilation by air-bricks or air-grids in the external wall in order to prevent the growth of a fungus—*Merulius lacrimans*—which in the presence of moist stagnant air develops on wood, giving rise to the condition known as "dry rot."

Where a building is erected below the level of the adjoining ground, contact of the soil with the walls of the basement should be prevented either by—(1) the provision of an "open area" several feet wide, and covered over with a layer of concrete around the building, or (2) by means of a hollow wall containing a "dry area" separating the damp wall in contact with the earth from the wall of the building proper. At its top and bottom the damp wall is joined on to the dry wall by means of some impervious material. The diagram explains the nature and position of these "areas." (3) By a sheet of mastic asphalt not less than ½ inch thick extending from the damp-proof course to a point above the ground where it is turned into a joint of the brickwork.

Dampness in a building may arise from—(1) dampness of the site, especially where a layer of concrete and a damp-proof course in the walls are absent; (2) rain passing down from the top of a party or parapet wall due to the absence of an impervious coping; (3) from the exposure of the house to driving

rain, especially if the walls are thin and the brickwork bad; (4) from the presence of "building-water" in the bricks and mortar of new houses (this dissipates in the course of a few months by the use of fires and free ventilation); (5) defects in the roof, gutters, or rain-pipes. Certain parts of the roof are particularly liable to be penetrated by rain—*e.g.*, the ridges, the valleys formed at the junction of roofs which run in different directions, and the points where the chimneys pass through the roof. In the case of the ridges it is usual to keep out the rain by ridge-tiles, and in the other situations sheet-lead is commonly employed. The terms "flashings" and "apron" are applied to the sheets of lead embedded in the chimney which overlap the roof on the lateral and under aspects respectively. A lead gutter is usually formed between the roof above and the chimney beneath where the latter projects through the former.

The **aspect and surroundings** of a house are important in determining the amount of light, air, and sunshine available for the inmates. A south or south-eastern aspect affords the greatest amount of sunshine and shelter, and on that account is to be preferred. The surroundings of a house should be such as to provide adequate lighting and a free circulation of air. The presence of parks, open spaces, playgrounds, etc., in a city facilitates **external ventilation**. There should be in front and rear of a building an open space equal in length to the height of the building. The height of a building in a street should not exceed its width. If a line is drawn from the top of the roof of a building which is the same height as the breadth of the street to the bottom of the wall of the house opposite, it will form an angle of 45 degrees with the ground. Such an angle is also formed by the sun's rays in the first weeks of April and September, so that in the intervening period the direct rays of the sun can reach the lowest stories in such a street. For the remaining seven months of the year the height of the sun in the horizon is lower, and so the lower stories receive fewer direct rays.

In back-to-back houses the absence of space at the rear prevents through ventilation, and a convenient means of disposal of refuse and excretal matter, and of course the rooms

behind are dark, especially the kitchens, sculleries, pantries, etc., on the lower stories. The erection of such buildings is now prohibited.

The ground surrounding a building should be kept clean and dry. In the yard the ground should be covered over with cement or glazed tiles, and if the house abuts on a street, the latter should have a proper fall for the rain to the sewers, which should be able to deal with the rainfall in all weathers, so that flooding of the houses may never result. Streets and roads may be macadamized, but such are dusty and dirty, or may be covered over with granite setts or wooden blocks. Wood pavements give rise to little noise, and in this respect are much superior to granite setts. At the present time asphalt is being extensively used for covering over the surface of streets, and has many sanitary advantages. It is somewhat slippery for horses, but a fall on it is rare, and as a rule the horse is uninjured. The smoothness resulting from the absence of joints is a great advantage possessed by the asphalt street.

For houses not more than 25 feet in height the Model By-laws of the Local Government Board prescribe a minimum thickness of 9 inches, and where the height is greater than this, the thickness of the walls must increase according to a prescribed scale—*e.g.*, 13½, 18, 22 inches, etc.

The bricks are bonded together with mortar, which consists of 1 part of lime to 3 parts of clean sharp sand. In the Flemish bond bricks set lengthways and endways alternate in the same course, whilst in the English bond courses consisting of "headers" and "stretchers" generally alternate.

Slates or tiles are used in the construction of the roof, and these should form respectively angles of 26 degrees and 45 degrees with the ground.

With the exception of the floors of the kitchen, scullery, and pantries, which are covered with tiles, the **floors** are usually made of wood, the planks of which fit into each other by grooved and tongue joints. In large buildings, fireproof flooring consisting of a sheet of concrete 4 to 6 inches in thickness, and supported by iron beams embedded in it, is now come into extensive use. Such floors are usually covered over

with wooden blocks 12 inches long and 1 inch thick, which dovetail into each other. The height of the ceiling should not be less than 9 feet, and need rarely exceed 12 feet.

The **lighting** is influenced to a large extent by the proximity to and the height of neighbouring buildings and trees, but adherence to Gwilt's rule, which provides 1 square foot of glass for every 100 cubic feet of room-space, will usually answer all requirements. If too much glass is inserted into the walls, the latter are weakened, and the cooling effect of the glass interferes with the proper warming and ventilation of the rooms. Windows should be situated in such a position in the wall as to afford an even distribution of light in the room, and their top should extend as near the ceiling as possible.

Every house must be provided with an adequate supply of wholesome water. The main pipe entering the building from the outside is termed the "rising main," and branches from this should supply the taps providing water for drinking and culinary purposes. At the top of the house the rising main discharges into a cistern, the flow being regulated by a ball-valve situated at the end of the pipe. Water-pipes are usually made of lead, and for an ordinary dwelling-house a pipe of ½-inch internal diameter is a common size. From its ductile quality, lead adapts itself to the turns and bends to which a pipe is subjected. Certain waters have the power of dissolving lead, and this plumbo-solvency, we have already seen, is due to the organic acids contained in supplies from moorland areas. To guard against the danger of Lead-Poisoning among the consumers of such water, neutralization of the acids is the first desideratum, and the second is the use of pipes made of other materials than lead. To prevent contact of the water with the lead, a lead pipe may be lined with tin or glass, but it is difficult to make proper joints in such pipes. Where iron pipes are used, they must be protected against corrosion either (1) by immersion at a temperature of 600° F. in Angus Smith's solution, consisting of 4 parts of coal tar, 3 parts of prepared oil, and 1 part of paranaphthaline; or (2) by Barff's process, which consists in the production of a coating of black magnetic oxide in the lining of the pipe.

PLATE X.

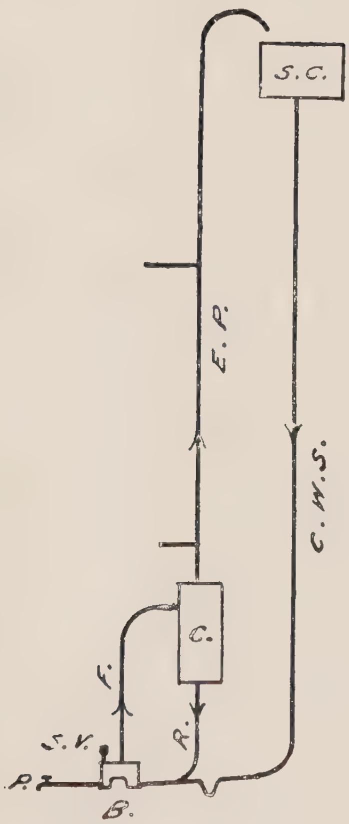

FIG. 21.—Cylinder System.

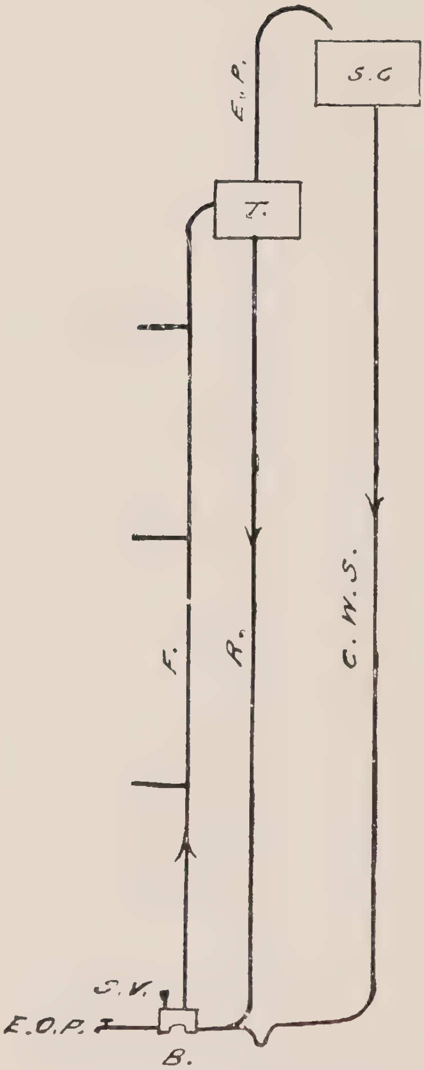

FIG. 22.—Tank System.

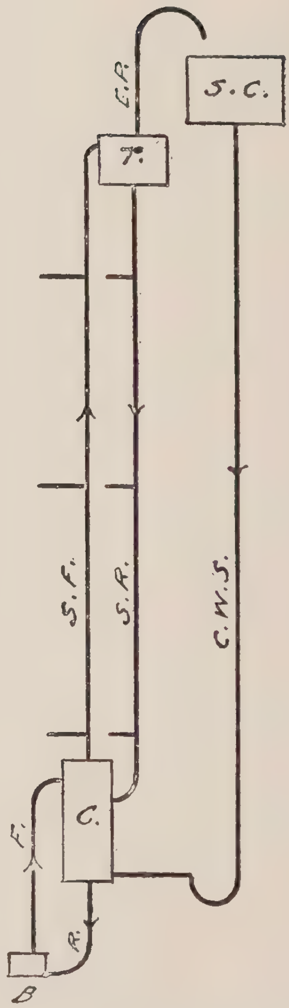

FIG. 23.—Combined Tank and Cylinder System.

In the diagrams *B.* = boiler, *S.V.* = safety-valve, *F.* = flow-pipe, *R.* = return-pipe, *C.* = cylinder, *T.* = tank, *S.C.* = cold-water cistern, *C.W.S.* = cold-water supply pipe.

(*From* Blake's "Drainage and Sanitation.")

Cisterns.—Galvanized sheet-iron cisterns are those commonly used, being light, cheap, and durable. Stoneware cisterns are too heavy for ordinary purposes, and the same applies to those built of slate slabs. In the latter case care must be taken that the joints are made with cement, and not with white lead. A cistern should be situated in an accessible position, should be covered over to prevent contamination from dust, as well as from dead birds, mice, cockroaches, etc. It should be surrounded with a case lined with non-conducting material as a protection against frost, and should rest upon a lead safe or tray, which would serve to receive, and by means of a waste-pipe convey away the water in case the cistern overflowed. There should be an overflow-pipe connected with the cistern itself, and also a pipe situated at the lowest level of the cistern for washing it out. The cistern should not be used to flush any closet, but between it and the closet a small intercepting or waste-preventing cistern should be placed.

Domestic Hot-Water Service.—In the arrangement for the supply of hot water to the baths, sinks, and lavatories, three principal methods are followed: (1) The tank, (2) the cylinder, and (3) the combined tank and cylinder. Figs. 21, 22, 23, indicate the course of the circulation of the water in the systems. It will be observed that in all cases there is a pipe conveying cold water from the cistern to the boiler, and that this pipe is trapped before joining the return-pipe, with which it enters the boiler. The best type of boiler is the boot boiler, being so called from its shape. The boiler should be made of wrought iron or copper, and the pipes used for conveying hot water should be galvanized wrought iron welded steam tubing. The sole of the "boot" is hollowed out to serve as a flue, and the latter is then continued either as a hollow up the back of the upper of the boot, or, better still, up its centre. A boiler of this shape exposes a wide surface to the source of heat. The boiler is situated at the back of the kitchen range, and it should be provided with an emptying-out pipe and a safety-valve. At the top and bottom of the boiler are the respective junctions with the flow and return pipes. In the cylinder system the flow-pipe enters near its top a cylinder situated close to the boiler, the return pipe being then a short length between the

bottom of the cylinder and the boiler. From the top of the cylinder a pipe is continued up so as to open over the cold-water cistern, and from this pipe branches are taken off to the various taps.

In the tank system the supplies to the various taps are taken from the flow-pipe before it reaches the storage-tank, which is situated near the top of the building. The tank is usually closed, and in order to allow for the expansion of the water in the system on being heated an expansion-pipe from the top of the tank discharges over the cold-water cistern. In the combined cylinder-tank system branches can be taken not only from the flow, but also from the return pipe, and the cold-water-supply pipe is usually connected to the cylinder, though it may be connected to the tank or the boiler. The general arrangement can be seen from Plate X.

The cylinder system is more costly than the tank, as the cylinder has to be constructed to stand a greater pressure, but it possesses the following advantages: (1) Hot water is obtained in a shorter time; (2) there is less loss of heat, the flow and return-pipes being short; (3) all the taps are supplied with water of the same temperature; (4) there is less risk of an explosion of the boiler if the cold-water supply from the cistern should fail, since it is impossible to completely empty the cylinder, all the draw-off taps being above it. We may here mention two other causes of boiler explosions: (1) Development of too high a pressure in the system through the blocking up by ice or some other obstruction of the expansion-pipe; (2) the furring of the boiler, leading to the iron of the boiler getting red-hot, and water coming in contact with it through a fissure in the fur.

Elsewhere in this book important points bearing on building construction are referred to in the consideration of such subjects as Ventilation, Heating, Warming, Disposal of Excreta and Refuse, Schools, Hospitals, etc.

CHAPTER X

WARMING, LIGHTING, AND VENTILATION

To be comfortable in this climate we prefer a sitting-room to have a temperature of 60° F. In the British Isles open fires find favour on account of their cheerful appearance, whilst on the continent and in America stoves are almost invariably used. An advantage possessed by the open fireplace is that it promotes ventilation in the room, but this may be carried to such an extent that most of the heat passes up the chimney. This was especially the case with the older fashioned **grates**, but since the experimental work of Teale in 1886 fireplaces are now constructed with a view to passing on the heat into the room. A good fireplace should (1) have little iron used in its construction, the back and sides being made of fire-clay; (2) the width of the grate at the back should be about one-third of its width in front, the splaying out of the sides facilitating radiation of heat into the room; (3) the fire-brick back should lean over the fire; (4) the flue should be throated and should be provided with a movable mantle; (5) since slow and efficient combustion depends on there being no current of air up through the grate, this condition should be complied with by the use of a metal shield, or economizer.

In Galton's ventilating grate, fresh air is admitted from the outside into a chamber surrounding the grate and chimney flue, and after being heated, passes into the room through an opening above the chimneypiece.

Coal is the fuel commonly employed in the open fire, but gas fires are coming into extensive use. In the latter case blocks of asbestos contained in the grate are heated to redness by means of Bunsen burners. The advantages claimed for gas fires are—(1) That their heat can be available at short notice; (2) that they are clean, not forming ashes; (3) that their extensive use would

mitigate the smoke nuisance commonly met with in towns. Disadvantages are—(1) That they are apt to render the air so dry as to be irritating to the throat, and in certain individuals to cause headache. The placing of a saucer of water near the fireplace assists in preserving the humidity of the air. (2) That they are rather more expensive than coal, but where water-gas is used this is not the case.

In Belfast, where a mixture of coal-gas and carburetted water-gas is supplied, the cost of 1,000 cubic feet is two shillings and threepence. A gas-fire burns on an average 20 cubic feet per hour.

Before dealing with other systems of heating it is necessary to consider the three ways by which heat travels—by radiation, conduction, and convection.

The heat that emanates from the front of an open fire is mainly radiant—*i.e.*, it passes out in straight lines without heating the air through which it passes. Dull black surfaces possess higher emissive powers for radiant heat than those that are bright, and also are better absorbers. The intensity of radiant heat is inversely as the square of the distance of the heated object from the source of heat. By conduction the fireplace and its immediate surroundings obtain heat from the fire, the heat being transmitted from particle to particle of these objects. Similarly, in hot-water pipes the pipes gain heat by conduction from the hot water circulating in them. By convection is meant the transmission of heat by actual motion of the parts of a heated fluid. The heat experienced when a hand is held over the fire or over any hot object is mainly conveyed by particles of air which, being heated through contact with the hot object, become lighter, and ascend.

Stoves give out far more heat into the room than open fires, and are therefore more economical. There are two types—(1) The closed stove which in the process of combustion makes use of the air of the room; (2) ventilating stoves, which are provided with an air-duct under the floor for the admission of cold fresh air into a chamber surrounding the fire, in which the air is heated and then ascends into the room. A good example of such a stove is the Musgrave.

The surfaces of stoves exposed to the fire should be lined with

fire-brick, since iron readily becomes red hot, rendering the air excessively dry and giving rise to unpleasant odours by organic matter in the air being charred from contact with the hot surface. Cast iron when hot can emit and transmit carbon monoxide, and so allow this poisonous gas to escape into the apartment. The reason why stoves are not popular in the home in this country is that they have not the bright appearance of the open fire, but this can be imitated to some extent by the use of red mica flap panels put on the front fire-door, especially with the slow combustion anthracite stoves.

Stoves, whether burning gas or coal, should always be provided with a flue to carry off the products of combustion. In a case coming within the writer's experience the absence of a flue led to the poisoning of two people by the carbon monoxide and dioxide resulting from the imperfect combustion of gas in a stove situated in a small shed in a builder's yard. Portable anthracite stoves are now coming into extensive use, but they should only be used for heating corridors, etc., and never a living or sleeping room.

It is an advantage to have the chimneys built in the inner walls of a house, since the heat passing up serves to dry and warm the walls of the rooms along its course.

Hot-Water Pipes.—The fact that water becomes lighter on being heated allows of its circulation through a closed system of pipes. Two systems are in common use—the low-pressure, in which at no part is the temperature above 212° F., and the high-pressure, or Perkins', in which the pipes commonly reach a temperature of 250° to 300° F. The component parts of the low-pressure system are—(1) A boiler with inlet pipe or return below, and outlet or "flow" pipe, above; (2) pipes usually 4 inches in diameter provided at intervals with radiators; (3) at the highest part of the system a tank communicating with the outside air by means of an expansion pipe. The boiler is situated in the basement and may be single or built up of sections. Along the course of the pipes expansion bends or expansion joints have to be provided to allow for the effects of the varying temperature to which they are subjected. Radiators serve to increase the heating surface, and according to their

position are classified as direct, indirect, and direct-indirect. The direct serve to warm the air in the room by radiation and by convection. The indirect, usually situated under the floor, warm the air passing over them before it enters the room through gratings provided. The direct-indirect, like the direct, is situated against an outside wall, and warms not only the air *in* the room, but also air entering from the outside through an air inlet situated behind it. The hot water, after circulating through the radiator, may rejoin the pipe by which it arrived (one-pipe system) or it may enter a special return pipe (two-pipe system).

Stop-valves are provided at the inlet of each radiator in order to permit of the regulation of the temperature, whilst at the side of the radiator near its top there is an air-valve to allow of the escape of any air accumulated in the pipe.

In Perkins' high-pressure system radiators as a rule are not used, the high temperature of the pipes being sufficient without an increase of radiating surface. The pipes are of strong welded wrought iron, $\frac{7}{8}$ inch in internal diameter and about $\frac{1}{4}$ inch thick. No boiler is employed, but about one-fifth of the total length of the pipes is coiled up and exposed to the heat of a furnace. The pipes are hermetically sealed, but to allow for the expansion of the water and to receive air given off from it in the pipes, an expansion chamber is provided at the highest part of the system. Instead of an expansion chamber, a weighted valve placed in a tank of water can serve to regulate automatically the pressure in the system by admitting water or emitting steam. In factories and public buildings, where steam is available, it may be employed as a warming agent in a system of pipes instead of hot water. As it condenses, steam gives up its latent heat, and the condensed water gravitates back to the boiler. "Water hammer," or noisy vibrations in the pipes, is liable to occur in this method.

Various formulæ are used by hot-water engineers in calculating the radiating surface required for the adequate heating of a building. In the low-pressure system about 12 feet of 4-inch pipe and in the high-pressure system 8 feet, are allowed for every 1,000 cubic feet of air space.

Electric radiators consist of resistance coils, which heat the

room mainly by radiation and convection. No products of combustion are formed, and the system is easily regulated. Expense prevents their general use.

Hot Air.—Air heated by passing over hot pipes is sometimes used not only for ventilation, but also for heating purposes. A uniform temperature can be readily obtained in this way. Dr. Leonard Hill, however, attempts to show that uniformity and monotony of cutaneous sensations are undesirable, maintaining that the ideal heating would correspond with that which prevailed out of doors on a spring day when a cool breeze tempered the radiant heat from the sun. The human body much sooner experiences a sensation of warmth and comfort when exposed to radiant than to convective heat. The modern gas fire is able to give off 45 per cent. of its total energy in the form of radiant heat, whilst from an anthracite stove only some 10 per cent. is given off in this form. In judging the efficiency of a system of heating and ventilation the sensations of the individual—the feeling of comfort and absence of discomfort—are safe guides.

Lighting.—Gas, oil, and electricity are the chief illuminating agents now in common use.

Coal gas is composed of—(1) Illuminants consisting of unsaturated hydrocarbons, chiefly olefiant gas and acetylene, amounting in all to about 4 per cent. The burning of these gases gives the flame its luminosity. (2) Diluents—*e.g.*, hydrogen, methane, carbon monoxide, etc.—representing 90 per cent. of the mixture. The combustion of these gives little light, but prevents the deposit of soot which would ensue if only unsaturated hydrocarbons were burnt. (3) Impurities consisting of nitrogen, sulphur compounds, and traces of carbon dioxide. Coal-gas contains on an average 6 per cent. of carbon dioxide. At the present time coal-gas is often supplied mixed with various proportions of "carburetted water-gas." Water-gas is generated by passing steam through coke raised to a white heat 2,000° F. The following reaction occurs:

$$C + H_2O = CO + H_2.$$

The water-gas is then carburetted by being mixed with hydrocarbons obtained by the vaporization of mineral oil spread over

a hot surface. Carburetted water-gas contains 30 per cent. of carbon monoxide.

It is carbon monoxide that is the chief poisonous agent in gas, and since the introduction of water-gas, the number of deaths due to accidental Gas-Poisoning has enormously increased. In America water-gas has been most extensively used, and in Massachusetts and Rhode Island the death-rate from poisoning by illuminating gas has been nearly equal to that of Scarlet Fever or Measles. In the interests of the health of the community the amount of carbon monoxide contained in an illuminating gas should not exceed a certain standard; but the cheap rate at which mixtures of coal-gas and carburetted water-gas can be supplied has encouraged municipal authorities to make an increasing use of them. An English Departmental Committee recommended a 12 per cent. limit, but so far no Parliamentary action has been taken. Since carbon monoxide is odourless, a person may unknowingly inhale a lethal dose; therefore illuminating gas should always contain strongly odoriferous substances. An atmosphere containing 0·4 per cent. carbon monoxide is poisonous if breathed for a few hours. Carbon monoxide is a cumulative poison and produces its effect by combining with hæmoglobin and preventing the latter carrying oxygen to the tissues.

The Welsbach mantle burner possesses great advantages, both on the ground of hygiene and economy, over the flat flame burner; in the latter luminosity is due to the heating of particles of carbon in the flame, in the former an asbestos mantle is rendered incandescent by a Bunsen burner. By the use of the Welsbach mantle it has been found that the consumption of gas and the production of carbon dioxide and heat are diminished almost by one-half, whilst the lighting effect of one incandescent burner is more than three times as great as that of the ordinary burner.

Lamp oil is obtained by the distillation of crude petroleum. With a view to the prevention of explosions, it has been suggested that the flashing-point—that is, the temperature at which the vapour of the oil ignites—of any oil used for illumination should not be less than 100° F. The combustion of oil vitiates the air to a greater extent than that of gas. "If a room were

lighted with exactly the same quantity of light by each of the various methods, the comparative vitiation of the air would be as follows: Candles, 1; oil lamps, 0·7; ordinary gas burners, 0·45; incandescent gas burners, 0·27; and electricity 0 "(Blake).

Electric light has the following advantages over coal-gas, oil, and candles: (1) No consumption of oxygen. The light emitted does not result from combustion, but from a metal or carbon filament in a vacuum resisting the passage of an electric current and becoming incandescent; (2) no products of combustion, and therefore cleaner and no injury to colours and fabrics by SO_2, etc.; (3) heat relatively slight; (4) resembles daylight in being rich in actinic rays.

Ventilation.—By this term is usually implied the removal or dilution of the products resulting from human pulmonary and cutaneous exhalations, and from the combustion of gas, oil, etc. In certain trade processes provision has also to be made for dealing with gases, vapours, effluvia, and dust. We have already seen that the site and surroundings of a building are important in determining its external ventilation.

A well-ventilated room should be free from smell, and should not feel stuffy to a person entering it from the open air. It should have a temperature of about 60° F., the air should have a relative humidity of about 70 per cent., and should be in gentle movement.

Amount of Air required.—One of the chief products of respiration is carbon dioxide, and although there is strong evidence that this gas is not responsible for the evil effects of a vitiated atmosphere, still it has been found that a determination of the amount of this gas present serves as a useful index of the state of the ventilation of a room; the carbon dioxide increasing more or less *pari passu* with the noxious agent or agents.

De Chaumont discovered that when, as a result of respiration, a room contained over 0·6 part per 1,000 of carbon dioxide, a person coming in from the open air found it stuffy. The amount of carbon dioxide in towns is, on an average, 0·4 per 1,000, so that 0·2 part per 1,000 could be added by respiration before the 0·6 per 1,000 is reached, and 0·2 part per 1,000, or 0·0002 part per cubic foot, was therefore taken as the limit of per-

missible respiratory impurity. De Chaumont made use of an equation which is exceedingly useful in many of the calculations necessary in ventilation problems. According to De Chaumont, the amount of fresh air to be supplied will vary directly with the amount of carbon dioxide produced in the room, and inversely with the permissible respiratory impurity. The equation is—$D = \frac{E}{r}$, where D = the delivery of fresh air expressed in cubic feet; E the amount of carbon dioxide produced expressed in cubic feet, and r the respiratory impurity allowed per cubic foot of air. If each individual in a mixed audience produces at rest 0·6 cubic foot of CO_2 per hour, and if the r is taken as 0·0002, then $D = \frac{0{\cdot}6}{0{\cdot}0002} = 3{,}000$ cubic feet, or this amount of fresh air should be supplied per head per hour.

The following examples will serve to show some of the applications of the equation:

What hourly supply of fresh air is needed for a lecture-room containing fifty persons in order that the air of the room may not contain more than 0·8 part of carbon dioxide per 1,000 volumes of air ?

$$D = \frac{E}{r}$$

$$\frac{50 \times 0{\cdot}6}{0{\cdot}0008 - 0{\cdot}0004} = 57{,}000 \text{ cubic feet.}$$

If 15,000 cubic feet of fresh air are supplied per hour to a room containing ten persons, what proportion of carbon dioxide will be found in the air of the room at the end of one hour ?

$$D = \frac{E}{r}$$

$$15{,}000 = \frac{0{\cdot}6 \times 10}{r}$$

$$15{,}000\, r = 6$$

$$r = \frac{6}{15{,}000} = 0{\cdot}0004$$

i.e., the respiratory impurity is 0·0004 part per cubic foot, or 0·4 part per 1,000, and as the fresh air contained already

0·4 part per 1,000, the total amount of carbon dioxide present is 0·8 part per 1,000.

It has been found in practice impossible to comply with De Chaumont's standard. Its adoption would involve the supplying of each individual with 3,000 cubic feet of air per hour, and as the air in a building cannot be changed by natural ventilation oftener than three times in the hour without a draught being produced, 1,000 cubic feet of space would have to be allowed to each person.

Carnelly, Haldane, and Anderson have proposed a more lenient standard, taking 1 part CO_2 per 1,000 instead of 0·6 per 1,000. On this basis the limit of respiratory impurity (r) is 0·6 per 1,000 cubic feet. From the equation $D = \frac{E}{r}$ we see that then $D = \frac{0{\cdot}6}{0{\cdot}0006} = 1{,}000$, so that with the air renewed three times an hour the air space for each individual would be 330 cubic feet.

The only instance in which a standard of purity of air has been fixed by law in this country is in the case of the artificially humidified air of cotton-cloth weaving-sheds. The maximum limit of CO_2 allowed at any part of the factory is 9 volumes per 1,000. This regulation is enforced only during daylight.

Fresh Air required for Artificial Lights.—The combustion of a cubic foot of gas produces 0·5 cubic foot CO_2, practically the same as that produced (0·6) by a human being in one hour. If we applied the same standards to gas lights as to human beings, a much larger volume of air would be required by the light, since the ordinary burner consumes 5 cubic feet of gas per hour. Since, however, the combustion of gas adds no organic matter to the air, it is usual to allow to each flat flame and incandescent burner two-thirds and one-half respectively the supply of fresh air required by an adult.

Size of Room.—Where a large amount of cubic space—*e.g.*, 1,000 cubic feet per head—is provided, renewal of the air of the room can be effected sufficiently often without disagreeable draughts. An excessive amount of space is no advantage, unless suitable inlets and outlets for air are provided; indeed, the most highly vitiated air met with by the Departmental

Committee appointed to consider and report on the Ventilation of Factories and Workshops in 1902, was in rooms with an air space of about 10,000 cubic feet per person, or forty times the legal minimum of 250 cubic feet per head.

There is no advantage in having ceilings of greater height than 12 feet, since the heated vitiated air is liable to collect in the upper regions unless the outlets are sufficient in number. To prevent this, it is well to have the top of the windows almost reaching the ceiling. Moreover, many of the products of respiration remain at the level at which they are produced, and it is at this level that pure air is required to dilute and remove them; floor space is therefore of greater value than height. The air on a still day over a dense crowd assembled in an open field may be stuffy, in spite of the unlimited height. In calculating cubic space, heights greater than 10 feet should not be considered in the reckoning. For certain places the minimum space per head has been fixed by law. Examples, expressed in cubic feet, are the following: 250 for workrooms, 300 common lodging-houses, 600 army barracks, 1,200 army hospital wards. We see that De Chaumont's standard of 1,000 cubic feet per person is a counsel of perfection, the attainment of which in most cases economic conditions render impossible.

Inlets and Outlets.—The volume of air that can enter or leave a building depends on the size of the inlets and outlets provided, and the rate of movement of the air. The rate at which air can be propelled without a draught being caused depends to some extent on the temperature. In artificial systems of ventilation, where the incoming air is heated, a velocity of 5 feet per second is quite comfortable. At a temperature of 60° F. air moving at a rate of 1½ feet per second (1 mile per hour) is imperceptible, at 2½ feet it is barely perceptible, but at 3½ feet is quite perceptible, and at greater velocities than this becomes a draught.

Every living-room and bedroom should have a chimney, and this, in most private dwellings, is the only special ventilation contrivance provided. A form of outlet often met with is Arnott's and Boyle's mica flap valves, situated close to the ceiling and opening into the chimney. The valve is suspended obliquely in such a way that it only opens when the heated

vitiated air of the room is at a higher pressure than the air in the chimney. The chinks in the windows and doors and the crevices in the flooring serve as inlets for air, and it is to be remembered that walls built of brick and plaster are porous and allow of a considerable exchange of air to occur directly through the wall. In public buildings, halls, workrooms, and offices, special ventilating openings are necessary. It is usual to allow per head as inlets and outlets openings of 24 square inches, and not to make the separate inlets larger than 60 square inches and the outlets not greater than 1 square foot. It is better to provide numerous small openings than a few large ones. The inlets should be situated above the heads of the occupants of the room, and the outlets should be as high up as possible. The relative position of inlets and outlets should be such that the entering air diffuses through the room before reaching the outlet. The air should have an upward direction on entering, so as not to impinge directly upon the occupants. Louvred openings, the width of which can be controlled by a lever, are often provided behind hot-water radiators, so that the air coming in from the outside is heated.

Ordinary sash windows, when open at top and bottom, and especially when placed on opposite sides of a room, serve to flush the room with fresh air, but this as a rule can only be tolerated during warm weather or when the occupants are engaged in some manual labour; such a procedure is most needful when schoolrooms, workrooms, and bedrooms are unoccupied. By raising the lower sash 1 foot and placing a board under it, air can pass into the room in an upward direction between the sashes where they overlap (Hinckes-Bird system). In schools, etc., it is expedient to have the upper part of the window revolving on a horizontal transome, so as to form a hopper-like inlet for the entering air. Sheringham's valve is on the same principle, and consists of a metal valve hinged in such a way that the air entering through the grating in the wall has an upward direction imparted to it. The size of the opening can be altered by raising or lowering a balanced weight. Tobin's tubes consist of perpendicular shafts, 6 to 9 feet from the floor, communicating at their base with the outside air and directing it above the heads of the audience in

a hall. Ellison's bricks, which are more frequently used in out-houses than in dwelling-houses, have horizontal trumpet-shaped perforations, the narrower aperture being directed towards the outside air so that the velocity of the current diminishes as it enters.

As exits for the vitiated air we have mentioned the chimney and the mica flap valve. Sheringham's valve, windows, etc., at times act as outlets. McKinnel's ventilator consists of two perpendicular shafts, one inside the other. These pass from the ceiling through the roof, and in order to prevent the entrance of rain, are covered over by a hood; the inner tube serves for the exit of heated vitiated air and the outer for the entrance of cold pure air. Shafts sometimes run from perforated openings situated at various positions in the roof of a building to a ventilating turret, where the vitiated air escapes through its louvred sides.

Natural Ventilation.—The appliances mentioned in the preceding section assist the process of natural ventilation, which depends on the following influences: (1) The diffusion of gases; (2) the difference in weight of masses of air unequally warmed and humidified; (3) the perflating and aspirating action of wind. By perflation is meant the forcing of air into a room through chinks in doors and windows, and even through bricks and plaster. On the other hand, wind blowing over the tops of chimneys and past the windows of houses tends to aspirate air from the room, and into the partial vacuum thus created fresh air enters. In a windy day the partial vacuum in the room may be so marked that the ordinary inlets are not large enough for the entry of sufficient air to neutralize the vacuum, so that air passes into the room from the chimney—there is a " blow down," and this can be avoided by opening a window or a door.

In dwelling-houses, especially in rooms provided with a chimney, a system of natural ventilation gives good results, but in the case of schools, theatres, factories, etc., where the space is limited, renewal of the air sufficiently often can be effected only by mechanical means.

Mechanical Ventilation.—Two systems are in vogue, the plenum, in which air is propelled into a building by means of

fans, and the extraction, in which an up-draught in a shaft serves to carry away the vitiated air.

The advantages claimed for the plenum system are—(1) That the amount of air supplied can be regulated; (2) that its quality as regards freedom from dust and such physical characters as temperature and humidity, can be regulated; (3) that it is uniform in its action.

There is no doubt that the plenum system can do all that is claimed for it, but the objections to it are serious: (1) It is expensive and requires skilled supervision; (2) the moist fabrics employed for filtering the air require frequent cleansing, as do the various air-ducts; (3) the opening of windows tends to derange the system; (4) the body is adapted to changes in the physical conditions of the air, and loses in tone in such an artificial environment. Probably the chief defect of the plenum system in the past has been that it attempted not only to ventilate, but also to heat a building. Air is a bad vehicle for the conveyance of heat. A combined system of plenum and natural ventilation gives in many cases excellent results.

For creating a draught in the extraction shaft with which the various rooms are connected by means of ducts, a variety of agents is employed—*e.g.*, fans, discharge of jets of steam, heating the air in the shaft by a fire or furnace at its foot, by hot-water pipes, or by the combustion of gas. In this system the quantity, quality, and source of the air supplied to the rooms cannot be so well regulated as in the propulsion system.

Determination of the Adequacy of Ventilation.—In deciding this question in a given case attention is directed to the following points: (1) Presence or absence of smell, (2) temperature and humidity as ascertained by the use of the wet and dry bulb hygrometer, (3) cubic space and floor space per head, (4) areas and situation of inlets and outlets and the velocity of the air at these positions, (5) amount of organic matter and number of bacteria in the air, (6) amount of carbon dioxide in the air.

Determination of the Amount of Carbon Dioxide in Air.—A brief description of Pettenkofer's method may be given: A large Winchester quart bottle is taken, and its capacity ascertained. It is then filled with the air sample, either by means of a pair of bellows or by filling it with water and pouring this out in the

room which is being examined. Fifty c.c. of a 0·5 per cent. solution of barium hydrate are introduced into the bottle and the contents shaken up. The CO_2 in the air partially neutralizes the barium hydrate by forming barium carbonate. The strength of the barium hydrate solution is ascertained before and after exposure to the CO_2, by means of a standard solution of oxalic acid, 1 c.c. of which is equal in neutralizing power to 0·5 c.c. CO_2 at N.T.P. In the titrations phenolphthalein is used as an indicator.

Example.—The capacity of bottle was 2,915 c.c., and when 50 c.c. of baryta were added to it, 50 c.c. of air were displaced, so that 2,915 − 50 = 2,865 c.c. were employed in the experiment. Fifty c.c. of the original baryta solution required 35 c.c. of standard oxalic acid to neutralize them, but the 50 c.c. exposed to the action of the CO_2 in the bottle required only 29·4 c.c.; therefore an amount of baryta equivalent to 5·6 c.c. of standard oxalic acid was neutralized by the CO_2 contained in 2,865 c.c. of air. But 1 c.c. of standard oxalic acid solution = 0·5 c.c. CO_2, therefore 5·6 c.c. oxalic acid solution = 2·8 c.c. CO_2—that is, there are 2·8 c.c. of CO_2 in 2,865 c.c. of air, or 0·98 part per 1,000. In practice it is necessary to reduce the volume of air to that found at 0° C. and 760 mm. Hg.

With Haldane's apparatus the volume of CO_2 in 10,000 parts of air can be read directly. The principle of the method consists in observing the diminution in a certain volume of air when the CO_2 in it has been absorbed by caustic potash.

CHAPTER XI

DISPOSAL OF EXCREMENTITIOUS MATERIAL

Conservancy System.—This is the old-fashioned dry system, in which privies or middens, earth or ash closets, receive the excreta. In the privy and midden no attempt is made to deodorize the filth which is deposited, either in a fixed or movable receptacle. The power possessed by earth of removing the offensiveness of fæcal matter has been known from time immemorial; it is now recognized that this effect is produced by bacteria present in the earth, and that an absorbent loamy soil is most suitable for the purpose. The earth should be dry, and should be sprinkled over the fæcal mass either by a hand-scoop or automatically delivered from a hopper at the back of the closet. On no account must slop waters or urine be placed in an earth closet, since this would lead to foul fermentation.

The buckets or movable receptacles may be lined with peat or sawdust or be smeared with petroleum. Well-fitting covers for the pails should be provided in all cases. The contents of these closets are usually used as manure, but if this is done, they should be first of all thoroughly mixed with freshly slaked lime. Burial in the soil in a position remote from any water-supply is probably the most convenient and safest method of disposal. If the material is sprinkled over a field, flies may carry bacteria contained in it and infect food.

The conservancy system is only suitable for country houses and villages; in towns the water-carriage system should be always adopted. **Privies** and **middens** should be at least 6 feet away from a dwelling, and should have other means of access for the scavenger than through the dwelling; they should be 40 or 50 feet away from any water-supply. The floor, and especially the receptacle, should be water-tight. Even where a

movable receptacle is employed, this should sit upon a floor of concrete-covered cement.

Where a water-closet is constructed in a place unprovided with sewers, the drainage is conducted to a cesspool or pit sunk in the earth. The walls of cesspools are frequently so porous that the water contained in them readily sinks into the soil, so that it is only at rare intervals that they require emptying. This practice is objectionable, since it allows unpurified sewage to pollute the subsoil water. When the foul water in a cesspool, on the other hand, is disposed of by being brought into contact with the upper layers of the soil which are rich in nitrifying bacteria, it is purified before reaching the ground water.

Cesspools should be (1) constructed of brickwork set in cement backed with a layer of puddled clay; (2) roofed over and provided with a ventilating opening and overflow pipe; (3) at least 50 feet away from a dwelling, and 60 to 80 feet from a well, spring, or stream; (4) disconnected from the drain by means of an intercepting trap.

In the cesspool the solids are in part liquefied and in part accumulate as sludge at the bottom. The overflow-pipe from a cesspool should discharge over a small bacteria bed made of clinker, or into a series of open agricultural drains embedded in the soil (subirrigation), or the contents may be sprayed or conducted in channels over the surface of a field (irrigation). We shall deal with the irrigation system later, but at this point a few remarks may be made regarding **subirrigation,** as by means of it slop waters can be dealt with in a sanitary fashion. The drain containing the slop water is led to a plot of ground of adequate size and suitable nature; four perches are sufficient for a cottage, and a loamy, porous soil gives best results and does not require under-draining. The drain communicates with a series of 2-inch agricultural porous pipes loosely jointed together, radiating out from it and situated at a depth of 8 or 12 inches from the surface. In cases where the distal pipes of the system are not reached by the water, which tends to soak out and saturate the ground at the proximal end, this can be avoided by conducting the water into a basin, which automatically tips over when it is full and thus flushes the whole system of pipes.

Water-Carriage System.—In this the excreta, surface and wastewaters are conveyed away from the premises along a drain-pipe, which leads into a sewer or into a cesspool. The water-carriage system possesses advantages both on the ground of convenience and hygiene; the excrementitious material is at once conveyed away from the premises, and the greater cleanliness and freedom from effluvia allow of the construction of the closet inside the house.

Since a town must provide sewers for its surface and waste water, and since the addition of excreta is found not to very materially alter the composition of the sewage, the adoption of the water-carriage system would not involve the Sanitary Authority in much extra expenditure, and would scarcely affect the problem of disposal of the sewage of the town.

The presence of excreta near a house is always a source of danger, since water may be contaminated, food may be infected by flies, etc., and the cleansing of such privies is always an offensive, if not expensive, process. The replacing of privies by water-closets invariably is followed by improvement in the health of the population, especially as regards the incidence of intestinal diseases. In Nottingham, in 1902, there were twice as many cases of enteric fever proportionately in " pail " houses as in w.c. houses, and fourteen times as many cases in " midden " houses as in w.c. houses. Probably different social conditions assisted in the production of this result, but in any case the figures are striking.

The **water-closet** is connected to the drain directly by the soil-pipe, while the waste and rain-water pipes discharge in the open air over a gully trap which communicates usually with a branch of the main drain.

At the present time the wash-down closet is the form almost invariably installed in dwellings. The essential parts of such a closet are the basin, with its flushing rim, and the trap, which in this form are cast in one piece and not, as in long and short hoppers, in separate parts. The closet is made of smooth glazed stoneware or porcelain, and to avoid soiling, the posterior wall is almost vertical, whilst the anterior is oblique. For flushing it, each closet should be provided with a small cistern containing 3 gallons, placed 3 feet above it, and connected with the

posterior part of the flushing rim by means of a lead pipe, 2 inches in diameter. The flushing water is derived from the household cistern, but only indirectly, the small flushing cistern intervening and serving to prevent any ascent of foul air from the closet to the large cistern.

The apartment in which the closet is placed should, if possible, be in a detached part of the house, and must communicate directly with the open air, and the closet should be in contact with the outer wall. The only woodwork about the closet is the seat, which is hinged behind, and may have a gap left in the rim in front to avoid soiling with urine.

The trap consists of a **U**-shaped bend, the hollow of the bend being filled with water, which seals it. The depth of the seal, being the distance between the bend of the smaller curve and the surface of the water, is 1½ to 2 inches. The momentum of the flushing water serves to carry the excreta through the trap into the soil-pipe and down the drain; in some closets the flushing water also enables a trap to be emptied by siphonage. Wash-out closets are objectionable, because soiling of the closet is frequent, and the obstruction offered by the basin dissipates much of the water's momentum, so that the excreta are frequently not carried further than the trap.

The closet is joined to the lead branch of the soil-pipe, which passes through the outer wall in the following ways:

1. By being directly soldered on to it, the porcelain or stoneware trap before firing in the kilns having been treated with a special composition to permit of this being accomplished—the metallo-keramic joint.

2. A brass collar is soldered on to the lead pipe by a wiped joint, and into this collar the end of the trap fits, the space between being filled in with cement, which is prevented from entering the lumen of the pipes by a layer of yarn.

The entire **soil-pipe** may be composed of lead, but usually is made of long segments of iron pipes, the joints of which are caulked with lead. To a **Y** branch of the iron soil-pipe the lead branch is connected by a caulked joint, the end of the lead pipe being furnished with a brass ferrule, which is received into a socket placed at the end of one of the **Y** limbs. To prevent corrosion, the interior of the iron soil-pipe is coated with Angus

Smith's varnish. The soil-pipe is usually 4 to 6 inches in diameter, and a pipe of the same calibre—the ventilating pipe—is continued directly up from it to open directly above the eaves of the house and as far away from windows as possible. The fewer bends there are in the ventilating shaft, the better does it serve its purpose—*i.e.*, act as an exit for drain air. The mouth of this pipe is covered with a wire cage to prevent birds building nests in it. The soil-pipe leads directly into the drain, being received by the socket end of a curved segment of the latter, cement being the joining material. If the soil-pipe is of lead, its distal end is provided with a brass ferrule.

The **drain** is usually made of glazed stoneware pipes, but where the ground is soft or where the pipes would be subjected to considerable strain, iron pipes, usually in 9-feet lengths, are used. Drain-pipes should not pass underneath a building, but if the site necessitates this, then the drain should be made of iron and should have no inlet into it inside the building, and should be surrounded with a 6-inch layer of concrete. To prevent settlements of the drain, a supporting base, composed of a layer of concrete 6 inches in thickness, is useful, and the joints should be made with cement. The usual diameters of drains are 4, 6, and 9 inches, and for these the respective gradients should be 1 in 40, 1 in 60, and 1 in 90. In such a drainage system the velocity of flow is 3 feet per second. The drain communicates with one of a series of larger channels—the sewers which are maintained by the Sanitary Authority, and which lead to the outfall station.

At the distal end of the drain, just before it joins the sewer, is placed an **intercepting or disconnecting trap.** This trap may be situated in an inspection chamber, the walls of which are made of glazed bricks set in cement, whilst the cement floor slopes down on each side to a hollow channel, having the same diameter as the drain. The roof of the chamber has a tight-fitting cover; an inlet for air into the chamber, and hence to the drain, is afforded by a grated opening or by a short shaft with a mica flap. Inspection chambers enable obstructions to be readily removed, and should always be provided where several branch drains join the main drain. The branch drains

before joining should curve round, so that the direction of the flow of their contents may be in the same direction as that in the main drain. To prevent "backing" of sewage into branch drains opening into a main drain, the level of the invert of the former should be above that of the latter, the height usually being equal to the difference in inches between the respective diameters.

The surface of the water in the intercepting trap should be 2 inches below the level of the flow of the drain, and the depth of the seal should be 2 inches. The inlet arm of the trap is almost vertical, while the outlet should be more oblique, usually at an angle of 45 degrees, so as not to offer too great an obstruction to the passage of the contents. On the proximal side of the trapping water a shaft leads to the surface of the ground, so that through it air may enter and ventilate the drain, an exit being provided by the ventilating shaft over the soil-pipe. An inspection eye or raking arm, which should, when not in use, be hermetically sealed, affords facilities for the removal of obstructions.

Advantages and Disadvantages of Intercepting Traps in House Drains.—This whole question has recently been investigated and reported upon by a Departmental Committee of the Local Government Board, and their conclusion is, that the disadvantages outweigh the advantages, although for at least thirty years the Local Government Board has insisted on their use. At the time when the interception trap was introduced, the potential dangers of sewer air were thought to be serious; hence the disconnection of the drains from the sewer. Now we know that, chemically and bacteriologically considered, sewer air is purer than drain air. An undoubted advantage of the trap is that it offers an obstacle to the entrance of rats from the sewer into the drain, an important consideration in the event of plague effecting a foothold in a town. The chief objection to the trap is that it forms a serious impediment to the passage of sewage from the house-drain to the sewer, and that this frequently results in more or less complete blockage of the drain. The sewage contained in the trap often gives off objectionable effluvia, which find an outlet through the ventilating opening of the trap, and thus cause a nuisance. The

trap is often improperly fixed, so that the sewage accumulates in the drain, which is converted into a cesspool. If the disconnection traps were abolished, the drains and their ventilation shafts would effectively ventilate the sewer.

Traps are structures which contain water, so situated that it opposes the passage of air or gases in a certain direction. The efficiency of the trap depends on the depth of the water seal, which is the height of the surface of the water in the trap above the elbow of the smaller curvature of the trap bend. Most modern traps are more or less **U**-shaped, and should be constructed of strong smooth impervious material, and there should be no angles in which filth might readily find a lodgment. A trap may be unsealed in the following ways: (1) By evaporation (this is only likely to occur where a closet is not used); (2) by the momentum of the flushing water being maintained to the very end of the flushing; (3) where a drain is unventilated and contains gas under pressure, the gas may force the trap or may be absorbed by the water in it and then given off into the air of the house; (4) by siphonage. This is liable to occur where closets in different stories are connected with the same soil-pipe, the rush of flushing water from the upper closets tending to aspirate the water in the traps situated at a lower level. The introduction of an antisiphonage pipe, which connects the trap on the distal side of the trapping water with the open air, prevents a vacuum being established in the segments of soil-pipes connecting the lower closets with the main soil-pipe, and so prevents siphonage.

We have already seen that traps are present in the closet, and that an intercepting trap disconnects the drain from the sewer; but traps are also found in the waste-pipes leading from baths, sinks, lavatory basins, etc., and these pipes, like the rain-water pipes, discharge over an open **gully trap**. In this trap there is a considerable depth of sealing water intervening between the drain at the end of which the trap is situated and the waste-pipes which empty into the trap. The waste-pipes usually discharge into the open air above the trap, the wide mouth of which is covered over with a grating. In stable yards, etc., where the surface washings contain much suspended matter, the gully-trap is often provided with a bucket-like

structure, lining the interior, by which the sediment deposited in it can be readily removed.

In large houses and hotels where much grease is present in the water coming from the sinks, and which tends to obstruct the drain as it congeals, special grease-traps are introduced. A **grease-trap** is a special form of **gully-trap**, but is much larger, so that a large volume of the waste water can accumulate in the trap and allow the grease contained in the water to rise to the surface and congeal. In the grease-traps the waste-pipe leads directly into the trapping water. The congealed grease may be removed by hand periodically, or it may be broken up by the flush of a Field's flushing cistern, and the fragments carried down the drain into the sewer.

Field's flushing cistern finds numerous applications in drainage works, as by means of it flushings may be carried out automatically at intervals determined by the rate of flow of water through the feed-pipe into the cistern. As the water rises in the cistern, it fills up the space between the exit-pipe and the bell-shaped dome covering it, and at length water flows down this pipe carrying air with it, whilst the water in the **D**-trap prevents the entrance of air from without, so that at length more or less of a vacuum is formed in this pipe. When the vacuum is sufficiently developed, water rushes from the cistern into the pipe, and in this way the siphon, of which the exit-pipe is the larger, and the space between it and the bell, the smaller limb, is completed, and the whole contents of the cistern are then discharged by siphonage.

The Testing of Drains.—Properly constructed drains should be air and water tight. To detect defects, the drains are filled with water, air, or smoke under pressure, or some strongly smelling substance is introduced into them.

The water test is a very severe one, and should only be applied to new drains, and only to the drain, not to the soil-pipe. The test is carried out before the drains are filled in. After the drain outlet has been closed with a pneumatic plug, the drain is filled with water to the level of the gullies, and then any decrease of water in the gullies beyond that due to evaporation, indicates the presence of a leak.

In the smoke test the smoke obtained from burning oily

waste is pumped into the drain, usually at the site of the disconnecting-trap, and evidence of the escape is looked for either in the drain or soil-pipe. The top of the ventilation shaft is, of course, sealed.

Air may be used instead of smoke, alterations in the level of a manometer indicating a defect. Smoke is preferable, as the site of the defect is more readily located. In the chemical test, glass capsules of phosphorus and asafœtida or of peppermint oil are introduced through the trap of an upper closet into the soil-pipe, and in it are broken by means of a cord and firing arrangement attached to them, or the contents escape when a paper band, which retains the cover of the capsule in its place, is removed. In the case of the oil of peppermint, several bucketfuls of hot water are subsequently passed down the closet to render it more volatile.

Sewers serve to convey the drainage to the outfall works, where it is disposed of. The sewage consists of surface and waste water, effluents from manufactories, street washings, etc., and usually liquid and solid excreta. It has been found that even where excreta are not added to the sewage the latter is foul and differs but little in composition from that of towns where the water-carriage system of excretal disposal is in use. The excreta from water-closets may be conveyed along a separate series of pipes, but usually excreta and surface waste water flow together in a combined channel. Where the separate system is in use, the sewers for the transit of excreta are smaller and more readily flushed, and the composition of the sewage is more constant, but the flushing effect of the rainfall is absent. In the combined system the sewers must be large enough to deal with the large volume of dilute sewage present during heavy rains, otherwise low-lying districts are liable to be flooded.

Up to 2 feet in diameter sewers may be made of glazed stoneware pipes, but for larger diameters the sewers are built of glazed bricks set in cement, and in order to diminish sedimentation and to afford a good scouring effect, the shape on section is elliptical, the smaller end of the ellipse being at the foot. The gradient of the sewer should be such as will give a velocity of 2 to 3 feet per second to the contents. Ventilation is usually effected by shafts leading from the crown of the sewer to the

roadway, the opening above being covered with a grating. These openings should occur at intervals of 100 yards.

In some cases metal shafts connected with the sewer and attached to neighbouring houses or trees have been used for ventilation purposes, and if the interception trap at the juncture of the house drain and sewer is abolished, then the sewer will be ventilated through the drains, their soil-pipes, and ventilation shafts.

Sewer Air.—In a well-ventilated and properly laid sewer the air differs but little from that outside. It is usually warmer and richer in moisture, and therefore lighter—facts which, taken in conjunction with the effect of the flow of sewage in drawing in air, explains the ventilation of the sewer. Where sewage stagnates in a sewer, putrefaction leads to the generation of foul gases, "**sewer gas,**" which are exceedingly poisonous. In such gas there are various compounds of caıbon, nitrogen and phosphorus. Carbonic acid gas, sulphuretted hydrogen and ammonium sulphide are present in large quantity, and men engaged in remedying the defects in the sewer may be overcome by these gases, and die. The action of the carbonic acid gas is slow, and is chiefly narcotic, whereas the sulphuretted hydrogen may produce a fatal result almost instantaneously through its paralyzing effect on the respiratory centre in the medulla oblongata. An atmosphere containing 0·2 per cent. sulphuretted hydrogen has proved fatal to those breathing it.

In the air of a moderately well ventilated sewer there is about three times more carbonic acid gas and twice the amount of organic matter present in the outside air. Curiously enough, the number of bacteria present in sewer air is smaller than in the open air. This is probably due to the settling of the bacteria on the moist walls of the sewer and to the fact that sewage flowing quietly does not give off any of its bacteria into the air above it. Where splashing of the sewage occurs and where bubbles of gas discharge from its surface, bacteria are detached, and may be carried by air currents many feet up the ventilating shafts. Horrocks has shown that this also readily occurs in household drains. Dried sewage matter adhering to the crown and sides of the sewer may become detached, and the bacteria

contained in it pass into the air. The bacteria characteristic of sewage—*e.g.*, *Bacillus coli*, *streptococci*—being absent as a rule from the sewer air, although a million of them may be present in 1 c.c. of the liquid, it is improbable that such pathogenic bacteria as the *B. typhosus*, *B. dysenteriæ*, *Vibrio choleræ*, are likely to have sewer air as their infective vehicle. A generation ago the dangers to health of sewer air were greatly exaggerated, and many outbreaks of disease were attributed to drainage defects on insufficient evidence. At the present time it is admitted that sewer air tends to lower the vitality and resisting powers of those who inhale it, and so predisposes to attacks of Tonsillitis and Pharyngitis, Diphtheria, Conjunctivitis, Diarrhœa, and Dysentery. Since drain air, bacteriologically and chemically considered, is worse than sewer air, there would probably be no danger in abolishing the intercepting trap provided the drains were properly constructed.

Disposal of Sewage.—If, as was formerly the custom, the sewage of a town is discharged in its crude state into a stream or river, a nuisance, due to decomposition and fouling of the banks, is almost certain to ensue, unless the volume of water in the river is enormous compared to that of the sewage. Even where the sewage of a town can be discharged into the sea, it should undergo some preliminary treatment—*e.g.*, removal of suspended matter. The sewage from the different quarters of a town is conveyed to the outfall sewer, and not unfrequently that coming from the low-lying districts will require to be pumped up to a higher level before it can reach the outfall sewer.

The sewage at the distal end of the outfall sewer is "screened" by passing through screens or sieve-like structures, the meshes of which are fine enough to intercept suspended matter of a greater diameter than $\frac{1}{3}$ inch.

Of screens there is an infinite variety; some are fixed, some are movable, some are at right angles to the current of flow, some inclined to it, some clear themselves of the intercepted matter automatically, others are cleansed by hand. The solids removed in this way are usually taken to a destructor and there cremated.

After passing through the screens the sewage flows over

"detritus" tanks, in which the heavier mineral particles, or silt, settle. By means of "screening" and detritus tanks 20 to 25 per cent. of the suspended matter in the sewage is removed. The sewage is now conducted into large open settling tanks or covered septic tanks, in which it is allowed to come to rest, or at least the velocity is reduced to less than $\frac{5}{8}$ inch per second. As a result of this stagnation, only 10 to 20 per cent. of the solids remain in suspension. These fine particles impart the turbidity to the sewage, and even a period of twenty-four hours in the tank fails to get rid of them. It is noteworthy that the Local Government Board insists that a town shall have sufficient tank accommodation to contain twenty-four hours' dry-weather flow of sewage. By the addition of chemical substances—precipitants—to the sewage before it reaches the tanks, bulky precipitates, usually aluminium and iron hydrates, are formed, which carry the finer particles to the bottom and so afford a perfectly clear effluent, and at the same time diminish the organic matter in solution to the extent of 20 per cent.

The chemicals are usually added in quantities varying from 5 to 15 grains per gallon, and quicklime and alum are almost invariably employed—*e.g.*, lime and alum, lime and sulphate of iron, alum and iron ("alumino-ferric"). In London 3·5 grains of lime and 2·5 grains of sulphate of iron are the reagents used.

The material that is deposited in these tanks is termed "sludge," and from time to time this has to be removed, so that it is necessary to have two sets of tanks, the one being in use whilst the other is being cleansed. The sludge is pumped out or removed by hand or by special mechanical contrivances. If the town is situated on the seaboard, the sludge is usually pumped into tank steamers, which carry it far out to sea and there discharge it. In inland towns the sludge can be conveyed to hollow ditches in fields and covered over with earth, or it can be converted into "sludge cakes" in a sludge press, which presses out a considerable amount of contained water. The sludge cakes can be used for filling up hollow ground, or can be cremated. The effluent, even from tanks where chemical precipitants have been used, is still putrescible, and should be discharged without further treatment only into a very large volume of water—*e.g.*, sea, estuary, etc.

Septic Tank.—Cameron of Exeter claimed that by keeping the sewage in the settling tanks under anaërobic conditions a considerable amount of digestion and liquefaction of the solids occurred, and that in this way the amount of sludge was considerably reduced. In the septic tank 70 per cent. of the solids settle to the bottom, so that in this particular it gives as good results as an open settling tank. The amount of digestion of sludge has been found, however, to be much less than was claimed for it by Cameron, probably less than one-third of the sludge is digested.

Authorities differ as to whether it is an advantage to treat sewage under anaërobic rather than under aërobic conditions. By septic treatment putrefaction results, with the formation of sulphuretted hydrogen and other gases, so that subsequent treatment of the sewage on "sprinklers" is likely to cause a nuisance in the neighbourhood, and also it is found that cement is liable to be corroded by such sewage. Septic treatment leads to a uniform mixture of the sewage, but whether subsequent purification is facilitated by the treatment is doubtful. Dunbar of Hamburg found that a preliminary septic treatment diminished the amount of sewage that could be dealt with by the contact beds in the day. The advocates of septic treatment claim that the organic matter is rendered unstable, and its subsequent breaking down in the contact beds is more easily effected.

Dibdin's Slate Beds.—The anaërobic treatment gives rise, as we have seen, to a foul effluent and deposit. It is claimed that treatment in beds under aërobic conditions produces a non-offensive deposit and effluent, and that Dibdin's slate beds are very suitable for this purpose. The beds are 4 feet deep, and contain slates laid horizontally and 2½ inches apart. The beds are filled with sewage, and allowed to remain full for two hours, and then are emptied and exposed to the air for another two hours. A certain amount of digestion of the solids deposited on the slates occurs, and this has to be flushed out from time to time. The deposit if at once disposed of is not offensive, but has a mouldy smell and contains much animal life. Treatment of sewage either in septic or other tanks or in Dibdin's slate beds does not remove the putrescibility of the sewage;

this object can only be obtained by further biological processes.

Biological Methods for the Removal of Putrescibility.—It is a matter of common observation that when mixed with earth foul organic material loses its offensiveness and is gradually resolved into simple salts and gases. The disposal of sewage on land may be regarded as a natural biological system of purification in contrast to the more artificial biological systems presently to be mentioned, but in both cases the purification is the result of the vital activity of micro-organisms. The earliest method of disposal of sewage on land is that known as **irrigation,** in which the sewage is used as a fertilizer, being distributed over the ground by a series of open channels and so brought into contact with the plants growing in the soil. These channels are usually situated along the top of ridges, which are 30 to 60 feet broad, the sewage trickling from the top of the ridge down the sides. Porous friable loamy soils are suitable, allowing the purified effluent readily to percolate and reach the subsoil drains, which are situated 5 or 6 feet from the surface, and which serve to convey it to the nearest watercourse. The crops usually grown on these sewage farms are Italian rye-grass, turnips, cabbages, etc. In some places—*e.g.*, Berlin—sewage farms effectively deal with large volumes of sewage, but the large amount of ground required and the expense entailed have led to the abandonment of this system by most towns. At best, an acre of land can only deal with **6,000** gallons of sewage per day.

The second method of land disposal is that known as the **intermittent filtration,** in which the purification of the sewage rather than the raising of crops is the primary consideration. It was soon found that clogging of the soil prevented filtration and purification, but Frankland showed that this result was not so liable to occur if the land were covered with sewage only for a portion of the day (six hours) and were exposed to the air during the remainder (eighteen hours). This discovery of Frankland's revolutionized the problem of sewage disposal, and subsequent developments recognized intermittency as a *sine qua non.*

The soil required is similar to that where irrigation is used, and, as in the latter, subsoil drains are necessary. The surface layers require ploughing up, and renewal from time to time.

In this method an acre of land can purify **30,000** gallons of sewage daily or even **90,000** gallons if precipitants have previously been used. The effluent from land-treated sewage is non-putrescible, 20 to 80 per cent. of the organic nitrogen and carbon being removed, and the number of bacteria may be so greatly reduced that the *B. coli* may be absent from 10 or even 100 c.c. In the latter particular land treatment possesses a distinct advantage over the artificial biological methods, which may now be considered.

Artificial Biological Methods.—Experiments conducted at Lawrence by the Massachusetts State Board of Health showed that filtration through coarse and porous material like gravel gave as good results as through land, and there was less tendency for clogging of the filter to occur. In these experiments the sewage was allowed to percolate through the beds, which were, in fact, filtration beds. At London the Massachusetts results were confirmed, and it was discovered that purification of the sewage occurred even if it were kept in contact with the material filling the beds, and were discharged only at stated intervals. Such beds are termed **contact beds** or **bacteria beds,** and consist of cement-lined tanks, 4 feet in depth, filled with clinker, coke, broken bricks, ballast, gravel, etc. The best filling material is that which has a maximum absorptive power and a minimum tendency to weather. The screened and sedimented sewage is first passed on to a bed filled with coarse material, having diameters from $\frac{1}{2}$ to 2 inches, and thence to a finer bed composed of particles with diameters ranging from $\frac{1}{16}$ to $\frac{1}{4}$ inch. In the working of contact beds the eight-hour cycle is a convenient one to follow, and gives good results—one hour to fill the beds, two hours full, one hour to empty, and four hours at rest exposed to the air.

In contact beds one acre in extent **500,000** to **1,000,000** gallons of sewage per day can be purified, the reduction of organic matter being usually about 70 per cent. Such beds require but little supervision, and are not liable to be deranged by weather conditions.

Percolating Filters ("Sprinklers").—In this method the liquid sewage is sprayed in fine jets intermittently over the beds, the effluent from one sprinkling being allowed to drain

away before a fresh dose of sewage is added to the bed. The beds, usually circular in shape, are 5 to 6 feet in height, and are freely exposed to the air. They are constructed of coarser material than the contact beds, and this is built upon a concrete base provided with hollow channels for the escape of the effluent. The sewage is distributed in fine jets and sprays over the surface of the bed by perforated pipes, which may be fixed or movable. In the case of circular beds revolving hollow arms, supplied with sewage from the hollow axle, sprinkle it over the surface, while longitudinal beds are usually provided with rails along which special forms of distributing appliances run. The advantages claimed for "sprinklers" over contact beds are—(1) They occupy less space; (2) require less filling material; (3) the latter, on account of the free exposure to the air and consequent escape of carbonic acid, less readily weathers; (4) greater oxidation of the organic matter occurs, resulting in an effluent rich in nitrates.

Possible objections to the employment of this system are—(1) That when a foul sewage is being treated, sulphuretted hydrogen and other gases readily escape into the air and may be a nuisance to the neighbourhood; (2) the distributing apparatus requires skilled supervision, and may be deranged by frost or snow.

Theories of Sewage Purification.—Frankland believed that the purification was due to the oxidation of the organic matter by the oxygen of the air.

It has been found that beds newly constructed do not give efficient purification, but that this ensues when the particles in the beds get coated over with a gelatinous scum rich in animal and vegetable life.

The view which was once widely held that the bacteria in the sewage and in the beds directly mineralized the organic matters during the slow flow of the sewage through the latter implied an almost incredible activity on the part of the bacteria, since it was shown in small experimental beds that purification occurred in ten minutes. The adsorption or colloidal theory of Dunbar has much to commend it; according to it the dissolved organic matter is first absorbed into the matrix on the surface of the filling material—a purely physical process—and

is there retained to be decomposed and oxidized by the micro-organisms during the period of aëration. The experiments of Dunbar and Carnwath have shown that both bacteria and oxygen are essential for purification.

In the bacteria beds there are, as well as bacteria, protozoa, vermes, and insects, and probably all these play a rôle in the purification process. It seems to be definitely established that during treatment there is a loss of nitrogen—*i.e.*, there is less nitrogen in the effluent than in the crude sewage. The loss may amount to 20 per cent. This may be due to (1) the action of denitrifying bacteria, which convert nitrates, etc., into gaseous nitrogen; (2) to the use of nitrogenous bodies as food by the living forms present.

Disinfection of Sewage.—The effluent from sewage treated in an artificial biological system usually contains as many bacteria as in its crude condition. Experiments have shown that effluents can be sterilized by the addition of chlorine, usually in the form of chloride of lime, even where the reagent is present only in the proportion of 1 in 10,000. Most Sanitary Authorities do not feel called upon to sterilize their sewage effluents, considering that if other authorities use the river into which the effluent has been discharged as the source of their drinking-water, the responsibility for its due purification lies with the latter. Moreover, it is found that pathogenic bacteria rapidly die and disappear from water without any special treatment.

Characters of a Satisfactory Effluent.—The desideratum in all cases is that secondary decomposition should not occur when the effluent is discharged into a stream. Where the volume of water into which the sewage is discharged is large—*e.g.*, sea, or tidal river—no purification beyond sedimentation may be required. In the case of towns discharging sewage into rivers of a size similar to those met with in this country, some form of biological treatment is required. The character of the crude sewage of different towns varies, depending on the amount of rainfall, water-supply, manufactories, etc. Curiously enough, the sewage of a town where the conservancy system of excretal disposal is employed differs but little from that of water-carriage towns. It is the organic albuminous matter in the sewage

that renders it putrescible, and the usual tests to determine the amount of this constituent are the estimation of the albuminoid ammonia and of the oxygen absorbed by the organic matter from a solution of potassium permanganate after four hours' incubation at 80° F. Domestic sewage is deprived of its putrescible character if purification is carried out to such an extent as to reduce the oxygen absorbed by 60 to 65 per cent. The saline ammonia and the chlorine in sewage cannot be resolved into simpler bodies, and their determination throws little light on the degree of purification of the sewage. In Belfast sewage the saline ammonia and chlorine average 2·5 and 10 parts per 100,000 respectively. Numerous analyses conducted by Professor Letts showed that in the case of the crude, screened, and settled sewage of Belfast the figures for albuminoid ammonia and oxygen absorbed after four hours at 80° F. were 0·7 and 7 parts per 100,000 parts respectively, and that after purification of the sewage on various biological experimental beds these were reduced to 0·25 and 1·9, a percentage purification of 64 per cent. as regards the albuminoid ammonia, and of 73 per cent. as regards the oxygen absorbed.

The Eighth Report of the Royal Commission on Sewage Disposal has recently (1913) been issued, and in it is discussed the question of the standards and tests to be applied to sewage and sewage effluents discharging into rivers and streams. The Commissioners concluded that the determination of the amount of oxygen absorbed gave the clearest indication of absence or presence of objectionable pollution, and that a direct estimation of the amount of dissolved oxygen taken up in five days was to be preferred to a determination of the amount of oxygen absorbed from permanganate in four hours. The Commission emphasizes the fact that the chief factor influencing the standard of purification necessary for a sewage effluent is the degree of dilution afforded by the stream. If 100,000 c.c. of river water into which an effluent is discharged do not normally take up more than 0·4 gramme of dissolved oxygen in five days, the river will ordinarily be free from signs of pollution. As regards turbidity, the water of a perfectly clean river carries with it less than 0·5 part per 100,000 of suspended matter, that of a rather dirty-looking stream about 2 parts, and

of a foul stream 3 parts, or even more. As a limiting figure for solids, 1·5 parts per 100,000 might be taken.

Nuisances indirectly due to Sewage.—Along the foreshore of Belfast Lough, especially on the County Down side, enormous masses of green seaweed are thrown up by the tide, and there undergo fermentation, resulting in the formation of sulphuretted hydrogen and volatile fatty acids, which are a nuisance, but apparently not a source of ill-health to householders in the neighbourhood. The researches of Professor Letts have shown—(1) That the seaweeds in question are *Ulva latissima, Enteromorpha compressa* and *intestinalis ;* (2) that the occurrence of *Ulva latissima* in quantity in a given locality is associated with the pollution of the sea-water by sewage; (3) that Ulva finds a ready pabulum in ammonia and nitrates, so that an effluent satisfactorily purified according to ordinary standards would encourage rather than diminish the growth of the weed.

A nuisance only arises when the weed is thrown up by storms on the foreshore and is allowed to rot there. The removal of the weed has proved so expensive, that Belfast has determined to follow the advice tendered by the Royal Commission on Sewage Disposal, which, after investigating the whole question, concluded that the only certain method of abolishing the nuisance was to deepen the water by reclaiming the "sloblands" along the foreshore, since the large areas of shallow water and sluggish tides in the Lough were the conditions most favourable to its occurrence.

DISPOSAL OF REFUSE.—In every household a certain amount of waste material has to be disposed of, and this is especially the case with shopkeepers. Much of this waste material consists of paper, rubbish, ashes, sweepings, and the refuse from the kitchen mainly of a vegetable nature. It has been found in practice that on an average ¼ ton of refuse is produced per head of population per year. Such material, readily undergoing decomposition and forming a breeding-place for flies, should be rapidly removed from the premises. The householder can easily reduce the amount by cremating much of it in the kitchen fire, but there will still be a considerable residuum to be disposed of. The introduction of covered metallic receptacles in place of the fixed brick ashpits

has facilitated the cleanly removal of the refuse from the premises to the vehicle in which it is conveyed to its ultimate destination. These bins should be emptied once or twice a week, the more frequently the better. The refuse has been, and still is, frequently employed for filling up low-lying building sites; but such accumulations of refuse, we have already seen in our consideration of building sites, are open to many sanitary objections.

Undoubtedly the most hygienic method of disposal is by cremation, although the expense is considerable, usually about 1s. per ton. The cremation is effected in low or high temperature destructors, in the latter a temperature of 1,500° to 2,000° F. being produced by means of a forced draught. The refuse is carted up an inclined plane and tipped into a space above the furnace, from whence it is shovelled down through circular openings to the back of the hearth, on to which it is raked by the furnace men. When the furnaces have once been kindled, the heat given off from the burning refuse is sufficient to completely cremate it, the calorific power being one-tenth to one-fifth that of coal. The organic fumes are destroyed either by having the flue placed at the front of the furnace, so that to reach it they have to pass over the hottest part, or by having a fire at the bottom of the flue. Destructors contain separate compartments or cells, each cell being provided with a separate hearth capable of burning 10 to 15 tons per day. It is estimated that ten cells suffice for a population of 100,000.

In the destructor can also be cremated condemned carcasses, waste organic material, etc., from slaughter-houses and premises in which offensive trades are carried on, as well as the matter removed by the screens through which sewage passes on its way to the outfall station.

By burning, the refuse is reduced to one-third of its bulk, the residue consisting of fine ash and clinker, the latter being utilized for making mortar, bacteria beds, etc. The heat generated produces sufficient steam to drive a mortar mill or blast fan, etc. The vans in which the refuse is removed should be covered over, and it is an advantage to have the refuse of busy thoroughfares removed during the very early morning hours.

CHAPTER XII

PERSONAL HYGIENE

In the promotion of the health of the community, Sanitary Authorities are often thwarted in their efforts by the ignorance and evil habits of many of the people concerned. Every individual is responsible to a great extent for the preservation of his own physical, mental, and moral well-being, and also that of his family. The State has done much in the past, and is likely to do more in the future, to improve the conditions under which people live and work, but for the hygiene of the home its inmates are responsible.

It is becoming evident that instruction in personal hygiene should form an important subject in the education of the child. Personal hygiene implies the keeping of the body clean, and the giving of due care to the efficiency of the various organs of the system so far as these are under the control of the will; under the latter heading is involved attention to habits, clothing, and exercise.

Cleanliness.—We have already seen that animal parasites convey many diseases, so that by keeping the body and clothing clean the risk of contracting such diseases is greatly diminished. Now, although it is not denied that people can live to a good old age without ever taking a bath, and that in the country, where no bathing facilities exist, this is the common habit in our own and other lands; still, for the promotion of self-respect, æsthetic comfort and well-being, bathing is a *sine qua non*. Where it is impossible to bath the whole body, the perinæum and feet should be well washed with soap and water at least once a week, the head once a month, the face daily, and the hands before every meal.

The cold or tepid bath causes a contraction of the superficial capillaries, and their subsequent dilatation during the rubbing

down following the bath gives a pleasant glow to the body. In certain individuals, as the result of circulatory or other trouble, such a reaction may not follow the cold bath, and this indicates that the practice should be discontinued.

Digestion.—In the chapter on Food the requisites of a proper dietary have been considered. The food should be plain and wholesome, and should be thoroughly masticated, and the individual should promote digestion by taking a short rest after the meal, and subsequently following this up by work or exercise.

The tooth-brush should be used at least every night and morning in order to remove fragments of food from the interstices of the teeth, and so prevent fermentation and caries. Where Caries of the Teeth or Pyorrhœa exist, the services of a dentist should be at once requisitioned. An unhealthy condition of the teeth, gums, or tonsils, is incompatible with perfect health. It has been abundantly demonstrated that many disorders of the stomach and many rheumatic troubles are due to unhealthy conditions of the mouth. Constipation is a frequent cause of headache, lassitude, and general ill-health. The regular action of the bowels is influenced by habits acquired in childhood, by diet, and by exercise. A movement of the bowels should occur at least once a day, and where this is not the rule, the individual concerned should endeavour, by the addition of fruit and porridge to the dietary and by the aid of exercise and massage, to promote the action without the use of drugs. After defæcation, the hands should be washed; attention to this rule would prevent many of the outbreaks of Typhoid Fever ascribed to "typhoid carriers."

An excessive amount of food, especially protein, exerts a strain on the liver, kidneys, and circulation, in dealing with the excretion of the waste products.

Alcohol, when taken immoderately, is admitted by all to be poisonous, and to be capable of causing such conditions as Cirrhosis of the Liver, Granular Kidney, Arterio-Sclerosis, Neuritis, and other nerve lesions. Alcoholism also undermines the moral nature, and by the poverty which it causes leads to the malnutrition not only of the drunkard, but also of his family. In such families disease finds easy victims. Alcohol in

moderate amount possibly does no harm, but for the young and for those in active life it is unnecessary and is apt to be abused; for the old, it may be useful as a stimulant. The consumption of light beer in quantities not exceeding 1 pint per day probably is beneficial, and certainly is not more harmful than the ingestion of the same amount of aërated mineral waters.

Smoking is injurious to growing boys. After twenty-one years of age, its moderate use is probably not attended with harm, but with advantage in some cases. Excessive smoking sometimes causes defective vision—Toxic Amblyopia.

Sleep.—The requirement of the average adult is seven or eight hours, but this is subject to considerable individual variation.

For young children twelve hours, and for girls and boys nine hours, should be allowed.

Exercise is absolutely necessary for children, so that in all towns there should be playgrounds provided. For adults engaged in manual and mental labour recreation of some sort is advisable. For the majority of people their occupation is dull and monotonous, so that some hobby which would add colour to their lives is desirable. Exercise taken merely for the sake of exercise soon becomes distasteful, hence the neglect that so often is the fate of dumb-bells and patent developers. Games in the open air into which emulation and rivalry enter always appeal to the Anglo-Saxon, hence the popularity of football, cricket, tennis and golf.

The effects of exercise are felt by every system in the body. The heart-beat is stronger and more frequent, but unless the exercise is excessive, is regular in rate and volume. The rate of breathing is increased, and as the heart sends more blood to the lungs, the gaseous exchange in the alveoli is greatly accelerated. In fact, the amount of oxygen inhaled and the amount of carbon dioxide and watery vapour expired may be three to seven times that dealt with at rest.

The cutaneous vessels dilate, and perspiration is free. The urine is diminished in amount, the colour is high, and there is an increase of uric acid, but not of urea. Muscular energy would seem not to be derived from protein compounds, since there is no increase in the total output of nitrogen.

Exercise renders the muscles firm and responsive to the will. By games the special senses are trained, the mind is elated, and the capacity for quick decision educated.

Amount of Exercise required.—In our consideration of food we saw that the amount of energy available from this source for the average man was about 2,500 to 3,000 Calories. It is estimated that one-sixth of this energy is used up in doing external and internal work. The latter includes the muscular activity of the heart, muscles of respiration, and digestion. For those engaged in a sedentary occupation, exercise equivalent to 100 to 150 foot-tons is sufficient to preserve the normal tone of the body. Probably double this amount is required for the internal work.

A fair day's work and a very hard day's work may be taken to be equivalent to 300 and 500 foot-tons. In walking on the level it has been shown by Haughton that the work done is equivalent to raising one's body and the kit carried a certain fraction of the distance covered. This fraction, known as the "coefficient of traction," varies according to the rate of marching. For two, three, four, and five miles per hour, it is $\frac{1}{26}$, $\frac{1}{20}$, $\frac{1}{16}$, and $\frac{1}{14}$ respectively.

The formula for calculating the work done in walking is as follows: $\frac{W + W' \times D}{2{,}240} \times C =$ number of foot-tons, in which W = weight of the person and W′ the weight carried, both expressed in pounds, D the distance in feet, and C the coefficient of traction. The following example shows the application of the formula. What is the work done by a man weighing 160 pounds in walking sixteen miles at three miles per hour? Then $\frac{160 \times 16 \times 5{,}280}{2{,}240} \times \frac{1}{20} = 301{\cdot}7$ foot-tons.

Clothing.—The main objects of clothing are to preserve the warmth of the body by protecting it against heat and cold, and to afford mechanical protection against injury.

Considerations of decency and adornment also demand attention. Wool, silk, cotton, linen and leather are the chief materials employed in the making of clothing. The warmth of clothing depends upon its heat conductivity, and this is mainly influenced by the amount of air it contains, so that a

garment of loose texture feels warmer than one which is more closely woven. Arranged in their power to conduct heat, the order is linen, cotton, silk, wool. Moisture can be taken up by clothing (1) into the capillary spaces between the fibres (here linen and cotton act more readily than wool); (2) into the substance of the fibre. This is known as hygroscopic moisture, and hygroscopicity is possessed in a marked degree by wool, less by silk, and much less by linen and cotton.

The fibres composing a garment can be recognized by microscopic examination. Woollen fibres are unbranched, and show transverse markings due to the imbrication of the scales; silk fibres are straight and structureless, and have no septa, such as are seen in linen fibres; cotton fibres are flat and twisted, and have thickened borders. The use of the microscope is necessary for the detection of fraud. The treatment of cotton by certain reagents converts it into flannelette, a substance possessing many of the qualities of the woollen flannel garment. Flannelette is very inflammable, and every year this quality is responsible for many burning fatalities. Cotton and linen, being good conductors of heat, are suitable for outer clothing in the tropics, and in such cases the colour should be white, since heat absorption is influenced by colour, and white absorbs least heat. From white, arranged in ascending series as regards their capacity for heat absorption, the colours are yellow, red, green, blue, and black.

Wool and silk are best suited for underclothing, since (1) they are bad conductors of heat, (2) their hygroscopicity enables them to absorb the perspiration, and to slowly part with it by evaporation, and thus to avoid the chilling effect of the rapid evaporation of the moisture which occurs when linen and cotton are soaked with sweat.

The clothing should not interfere with the functions of the skin, and should not contain any colouring-matter liable to cause irritation; neither should it unduly constrict or compress any part of the body, nor hamper the natural action of the muscles. Fashion at home and abroad often disregards such obvious hygienic requirements.

Sexual Hygiene.—Adolescents of both sexes should be instructed with regard to the physiology of reproduction. This

duty would best be performed by the parents, but, unfortunately, the latter have failed in this duty either through want of inclination or knowledge. Lack of knowledge need no longer be an excuse, since there are now several books on the market in which the needful information is conveyed in a way which has won the imprimatur of the medical profession and of the leaders in the Church.

The serious toll of life and suffering imposed by Venereal Diseases, not only on men, but also on innocent women and children, rightly demanded investigation. It is to be hoped that the findings of the Royal Commission on Venereal Diseases which is now sitting may go a long way towards their prevention in the future.

CHAPTER XIII

SCHOOL HYGIENE

SINCE the introduction into England in 1908 of a system of Medical Inspection of School Children, much attention has been directed to the hygiene both of the school and the child. Unfortunately, in Ireland no such system has yet been instituted, and besides this disadvantage, the Irish child suffers from the fact that the school premises are often insanitary and overcrowded, their erection and control being as a rule vested, not in public and representative bodies, but for the most part in Churches of various denominations.

It is most important for the advancement of hygiene that the school in all matters relating to health should serve as a model to the home.

As regards the construction of the school, the same means to secure freedom from dampness, good lighting and ventilation, adequate heating and sound sanitation, apply as in the case of other buildings.

The **Site** should be central, but should be removed from the noise of traffic. To secure proper lighting and ventilation, there should be an open space surrounding the school. The width of this space will be adequate if a line drawn from the bases of the school walls to the tops of the surrounding houses does not form with the ground an angle greater than 30 degrees. Part or all of this space can be utilized as a playground. There should be 30 square feet for each pupil. In towns, the surface of the playground should be asphalted, a process which affords a clean, resilient surface. Part of the playground should be covered over for use in wet weather.

The School Building.—A south-eastern aspect affords a maximum amount of sunshine and ample lighting. Large schools should consist of a number of classrooms, which may

be grouped round a central hall. A better system is that in which the classrooms are connected by corridors 8 to 10 feet broad, which run along one side of the room, and which are provided with windows opening both into the classroom and into the outer air, and so permitting of a moderate amount of through ventilation. From considerations of the visual acuity of the pupils and the vocal energy of the teacher, it has been found that a length of 30 feet is suitable, and a breadth of 20 feet and a height of 13 feet satisfy the requirements of lighting, acoustics, and ventilation. The classroom is therefore almost invariably rectangular, having length and width in the proportions of 3 to 2 or 5 to 3.

Schools should not contain more than two stories, the stairs should be fireproof, and the doors at their foot should open outwards.

The windows should be situated on each side of the classroom, but those on the left of the pupil should be larger, so that the chief illumination comes from this side, and thus avoids shadows being thrown on the paper when the pupil is writing. Large windows directly in front of the pupils' eyes cause glare, and are to be avoided. The area of glass should be one-tenth to one-fifth that of the floor-space, and the amount of light should be such that a child with normal eyesight in the worst-lighted part of the room can read with ease small pica type at 12 inches from the eyes.

The window-sills should be 4 feet above the floor, and their tops should be carried up to the ceiling.

The windows should be made to open. The upper panes should incline into the room, forming Sheringham valves, and the lower halves of the windows should be capable of being raised or opened in casement fashion, or provided with hoppers.

The floors should be of wood, and should be polished with beeswax, and there should be no crevices in which dust could lodge. For some years in America and on the Continent linoleum has been used over the wood, and the ease with which it can be cleansed and polished should commend it to the School Authorities of this country. The angles formed by the walls with the floors and ceiling should be rounded off, and the surface of the walls above the cement dado should be

treated with some form of sanitary distemper or wash, preferably of a light green colour, since this increases the brightness of the room by reflecting light rays to a greater extent than most colours.

The **Heating** is best effected by low-pressure hot-water pipes, assisted by open fireplaces provided with fireguards. A suitable temperature is 60° F., but this may be slightly increased in the infant department. It should be seen to that the temperature is not preserved through fresh cold air being excluded to a greater extent than is necessary for adequate ventilation. If stoves are employed, they should be of the ventilating type.

Ventilation.—The amount of floor-space prescribed by the Board of Education for each pupil is 10 square feet, which will afford at most 140 cubic feet of space. This is quite inadequate to allow of the sufficient dilution of the impurities of the air by ingress of pure air without a draught resulting. The plenum system is in use in several schools, but is not to be recommended, since it is expensive, and the keeping of the windows closed is not an example which should be set to the pupils. A combination of the plenum and the natural system has given good results in some institutions. In the natural system, Sheringham valves and the windows serve as inlets, whilst the chimney and shafts running from the ceiling to a dome with louvred sides on the roof serve as outlets.

Ventilating stoves also assist ventilation. The upper panes of the windows should be constantly open, and in warm weather and during recess the lower halves of the windows should also be raised. The presence of windows in opposite walls enables the room to be purified by a current of air sweeping across it. In cases where the windows on both sides communicate with the open air, the perflating action is very marked, and even where those on one side communicate with a corridor a certain amount of flushing of the room with pure air is obtained if the windows are widely opened. The presence of the corridor allows of through ventilation during occupation of the room without unpleasant draughts arising.

Sanitary Conveniences.—Some few years ago trough-closets were recommended, and extensively adopted in schools, but at

the present time separate closets are taking their place. It is advisable to have the sanitary equipment in a separate building unconnected with the school, or at any rate in a detached tower united to the main building by a cross-ventilated lobby. In the case of country schools, some form of earth closet should be used, and it should be situated at a distance from the main building, and the strictest supervision should be exercised over its use.

In mixed schools, the sanitary conveniences for the boys and girls should be widely apart. One closet and one urinal for every twenty-five to forty pupils will usually suffice.

In some modern day-schools baths are provided, and it has been found that spray or douche baths are more hygienic than the plunge form.

A supply of wholesome water for drinking purposes should be available, and some form of fountain which delivers a fine jet of water which can be received directly into the pupil's mouth without the use of a cup is to be preferred.

School Furniture.—An important point to attend to in the equipment of the school is to avoid ledges, cornices, etc., where dust could readily collect. Blackboards should be provided with chalk-troughs to prevent dissemination of the chalk-dust. The use of slates should be discontinued, as the practice of cleansing the slates with saliva might readily convey such diseases as Diphtheria.

The desks should be arranged at right angles to the side-wall on the left of the pupils occupying them. There is great variety in the type of desk found in schools, a few being provided with a separate desk and seat for each pupil, others with a continuous desk and continuous seat. The Sheffield system, in which there is a continuous desk and a separate seat, has much to commend it. On a form a space of 20 to 24 inches should be allowed to each scholar. The height of the desks and seats should vary with the classes. Children differ so much in height, even when of the same age, that it is difficult or impossible to have desks that suit all the scholars. The height of the seat from the floor should be equal to the length of the pupil's leg, and its breadth should be equal to two-thirds the length of the pupil's thigh. The desk 15 inches in

breadth should be inclined at an angle of 15 degrees, and a line drawn from its anterior edge at right angles with the floor should just touch the anterior edge of the seat. When the anterior edge of the seat is in front of this line, the desk is said to be "plus," and this is more conducive to a natural posture of the body than is likely to be assumed where the desk is "minus," the edge of the seat being behind the line.

Stands for cloaks and hats and caps should occupy a well-ventilated apartment, or **Cloak-room,** connected with the schoolroom by a lobby. Where hot-water pipes are available, these should run underneath the racks to assist in the drying of the garments. There are special stands constructed of a series of hot-water pipes provided with pegs which are very suitable for this purpose. The distance between the pegs should be 12 to 18 inches, so that the coats may be as little in contact with one another as possible.

Cleansing of School.—At the end of every day the windows and doors should be opened wide, and the floors swept after being moistened to keep down dust. On every Saturday in the infant department, and on every alternate Saturday in the other classrooms, the floors, seats, and desks should be scrubbed with soap and hot water.

Supervision of the Child's Health.—In schools children are brought into intimate association with each other, so that there are ample opportunities for the spread of disease.

Medical inspection of school children is beneficial, not only to the child suffering from disease and mental and physical defects, but also to his companions. The School Medical Officer usually inspects each child three times during his school course, and the parents' attention is called to any defects met with, and to the necessity of these being medically treated. The fact that the Annual Report, 1911, of the Chief Medical Officer of the Board of Education shows that in England and Wales 10 to 15 per cent. of the children present signs of Defective Nutrition, and 75 per cent. of Dental Caries, that 18 per cent. are Verminous, 13 per cent. have Eye Defects, 5 per cent. suffer from Adenoids, 2 per cent. from Defects of Hearing, 1 to 2 per cent. from Ringworm, 1·5 per cent. from Heart Disease, and 1·5 per cent. from Tuberculosis, indicates that medical in-

spection and medical treatment of school children is required in the interest of personal hygiene and the health of the nation.

Local Education Authorities have power to provide for the treatment of defects found, but so far attention has been mainly directed to their discovery. The treatment, it is suggested, could be obtained at hospitals, towards the support of which the Authority is empowered to make contributions, or at School Clinics, consisting of local medical men; but the responsibility for treatment in the main rests with the parents.

Many Authorities supply spectacles free, or at cost price. The treatment of minor complaints is carried out by the School Nurse, who assists the School Medical Officer. For the cure of Ringworm in some districts X-ray appliances have been installed by the Educational Authority.

After-care Committees of voluntary philanthropic workers assist in enabling the parent to get his child medically attended to, but it must be admitted the treatment of school-children by the State is at present only in its experimental stage.

An important consideration in national hygiene is the education of teacher and pupil in the rudiments of physiology and hygiene. It is to be deplored that these subjects are either absent or occupy an insignificant place in the school curriculum.

In the prevention of the spread of infectious diseases by schools there must be, and usually is, a well-thought-out scheme of co-ordination between the Medical Officer of Health and the School Medical Officer. In many cases both posts are held by the same person, or the School Medical Officer is the assistant to the Medical Officer of Health. In the case of some epidemics it may be thought advisable to close the school, but very seldom will this extreme measure be indicated. In country districts, where the children meet only at school, such a measure may be justified; but in towns the children will meet frequently for play when the school is closed. The usual measure adopted is the exclusion of all children from affected households, the children being allowed to return only when their house and clothing have been disinfected, and they themselves are declared by a certificate from a medical practitioner to be no longer infectious. In the case of Diphtheria, bacteriological examinations of swabs taken from the throat of the convalescent

and " contacts " should have been found negative on three occasions before the children are admitted back to their classes.

The risk of contracting and succumbing to an infectious disease through attendance at school is diminished if such attendance is not begun until the child is seven years of age.

The School Medical Officer has power to exclude children from school—(1) On the ground that their exclusion is desirable to prevent the spread of disease; (2) on the ground that their uncleanly or verminous condition is detrimental to the other scholars; (3) on the ground that, owing to their state of health or their physical or mental defects, they are incapable of receiving proper benefit from the instruction in the school.

The Education Authorities provide facilities for the cleansing of children and their clothing from vermin, and are empowered to prosecute the parents if they permit the child to become verminous again.

Educational Authorities have power to provide special schools for defective children—*e.g.*, open-air schools for tuberculous children, schools and " colonies " for the education of the blind, deaf and dumb, defective, and epileptic children. Since it has been found that in many cases the children attending school are unable to take full advantage of the instruction provided, owing to their defective nutrition, Educational Authorities in many places have made use of their powers to provide meals for such children.

It is a truism that the health of the next generation lies with the school-children of to-day, and surely the time has now arrived for the instruction of the senior scholars in the rudiments of eugenics and hygiene. In the case of children leaving school at an early age, they should be compelled to attend continuation classes, where the duties of parenthood would be put before them by competent teachers. The Royal Commission on Physical Deterioration suggested that " the course of instruction at such classes should cover every branch of domestic hygiene, including the preparation of food, the practice of household cleanliness, the tendance and feeding of young children, the proper requirements of a family as to clothing—everything, in short, that would equip a young girl for the duties of a housewife."

CHAPTER XIV

INDUSTRIAL HYGIENE

On leaving school and entering factories and workshops, factory hygiene takes the place of school hygiene. The Factory and Workshops Act of 1901 consolidates the previous Factory Acts, and aims at the carrying on of industries under conditions as little injurious as possible to the workpeople. Since 1833 there has been inspection of factories in England, and this work is under the control of the Home Office, not of the Local Government Board. There is a Chief Inspector of Factories, who resides in London, and is under the Secretary of State, to whom he reports the work of his department. Throughout the manufacturing areas of Great Britain and Ireland there are Factory Inspectors (appointed by the Home Secretary), whose work is supervised by Superintending Inspectors, also residing in the district, but all these inspectors are subject to the control of the Chief Inspector. There is thus centralization of factory inspection in the kingdom. By the Factory and Workshops Act, inspection of factories is entrusted for the most part to the Factory Inspectors, whilst this duty in the case of workshops rests with the Local Authority. In the Act factories are taken to include (1) all places in which mechanical power is used in aid of the manufacturing process, (2) certain other industries, whether power be used or not. These are trades generally associated with dust, noxious fumes, or gases. Plans of new factories, like those of all other buildings, must be submitted to the local authority for its approval. This is most important, seeing that the strength of the foundations and the structure of a building to be equipped with heavy machinery should be assured. It is also the duty of the local authority to ensure that every factory and workshop has adequate provision for the escape

of the employees from fire, to see that certain sanitary defects found in factories, and remediable under the Public Health Acts, are abolished when its attention has been called to them by the Factory Inspector. In other sanitary matters pertaining to factories, the administering of the Act devolves upon the Factory Inspector. The hygiene of a factory and of a workshop is in general very similar to that of the home, but in addition the nature of the several manufacturing processes calls for special provisions. Cleanliness, including the lime-washing of the walls at stated periods, is insisted upon. With a view to adequate ventilation, there must be at least 250 cubic feet of air space for each worker, and during overtime 400 cubic feet per head must be provided for women. The general ventilation must be efficient in every workroom of a factory or workshop, and any standard fixed by the Home Secretary must be observed. Dust, gases, vapours, and other impurities generated in the work which are a nuisance or injurious to health must be rendered as harmless as possible. This is usually effected by the use of exhaust shafts, into which the injurious agents are drawn. In every factory or workshop where lead, arsenic, or other poisonous substance is used, suitable washing conveniences must be provided for the use of the workers, and the latter must not be allowed to take their meals or to remain during meal-times in any room where such substances are used.

By the Act, every medical practitioner attending on or called in to visit a patient whom he believes to be suffering from lead, phosphorus, arsenical, or mercurial poisoning or anthrax contracted in any factory or workshop, must send to the Chief Inspector of Factories in London a notice, stating the name and address of the patient, and the disease from which he is suffering. In the future there will be few notifications of phosphorus-poisoning, as the White Phosphorus Matches Prohibition Act, 1908, enacts that no person may use white phosphorus in the manufacture of matches, nor sell, offer for sale, or import, such matches.

With a view to the prevention of accidents, all mill-gearing must be properly fenced, and the machines themselves must be protected if the Factory Inspector requires it. Children

are forbidden to cleanse machinery in motion, while women and young persons are forbidden to cleanse mill-gearing.

Temperature and Humidity.—The air of every workroom must be kept at a reasonable temperature, which is taken to be 60° F. for sedentary occupations, and a lower temperature where there is much manual labour. It is difficult to make a maximum standard, as many trade processes require a high temperature, and also in many instances a high degree of humidity. This is notably the case in certain textile processes. In these cases where artificial humidity is produced, hygrometers (wet and dry bulb thermometers) must be kept in the rooms, and two or three readings taken daily at certain hours.

In workshops in which women are employed, and in which the floors are liable to be wet, adequate drainage must be provided for removing the excess of the fluid.

Sanitary Accommodation.—Every factory and workshop must be provided with sufficient and suitable conveniences for the workers, and with separate accommodation for each sex. The Act enabled the Secretary of State by special order to determine what is sufficient and suitable accommodation. Accordingly, the Sanitary Accommodation Order, 1903, was issued. Its chief provisions are that there shall be one sanitary convenience for every twenty-five females, and one for every twenty-five men. Where there are more than 100 men employed, and sufficient urinal accommodation is provided, one convenience for every twenty-five up to the first 100, and one for every forty after this, are deemed sufficient. Where the number of males employed exceeds 500, and the District Inspector of Factories certifies that there is proper supervision and control in regard to the use of the conveniences exercised by officers, specially appointed for that purpose, one sanitary convenience for every sixty males is sufficient in addition to sufficient urinal accommodation. Provision is also made for the ventilation and lighting, accessibility and cleanly state of the sanitary conveniences.

Home-Work.—Certain of the sections of the Factory and Workshops Act give important powers to the Sanitary Authority with regard to the conditions under which home-work is done. It is necessary for those who employ outworkers engaged in

certain classes of work, especially those relating to clothing and upholstery, to furnish to the Sanitary Authority twice a year a list of the names and addresses of their employees. On receipt of a notice from the Sanitary Authority that the place where the work is carried on is injurious to the outworker, the employer must then cease, within one month of the notice, to give out work to be done in that place. No employer, subject to a penalty, must knowingly give out wearing-apparel to be handled in a house where there is a case of Smallpox or Scarlet Fever. If an inmate of an outworker's house is suffering from a notifiable infectious disease, the Sanitary Authority may by order prohibit the employer from giving out any work to that house. This applies chiefly to the making, mending, cleaning, etc., of wearing-apparel.

A most important part of the Act is that which regulates the age at which children can enter a factory or workshop, and the number of hours worked per week. The Home Office appoints Certifying Factory Surgeons, whose duty it is to examine those under sixteen years of age who enter a factory, in order to ascertain if they are fit for the work. Children under twelve years of age must not be employed in factories or workshops. Above twelve, they may work half a day in the factory, and during the other half they must attend school. Young persons are those between fourteen and eighteen, and are eligible for full-time employment with certain limitations. A woman must not be employed within four weeks after giving birth to a child.

The period of employment for women and young persons in textile factories is on ordinary days twelve hours (6 a.m. to 6 p.m., or 7 a.m. to 7 p.m.), a two hours' interval being allowed for meals. And on Saturdays six hours (6 to 12 or 7 to 1), with half-hour interval, or 6 to 12.30, with an hour interval; or a weekly total of fifty-five and a half working hours. In non-textile factories, and in workshops and in laundries, the total working hours in the week is sixty. Certain holidays, amounting to six days in the year, are prescribed, and work on Sunday is prohibited. None of the above provisions apply to men over eighteen years of age.

By the Shop Hours Acts no young person can be employed

in or about a shop for a longer period than seventy-four hours, including meal-times, in any one week.

Through the operation of the Factory Acts, every fatal accident is carefully investigated, and the circumstances attendant upon each death in a trade believed to be dangerous to health are carefully sifted, so that precautions may be taken in the future.

Certain trades are scheduled as unhealthy, and are only allowed to be carried on subject to certain regulations. The Workmen's Compensation Act, 1906, by making it the duty of an employer to compensate a workman for injuries sustained in his employment, or in the event of the workman's death those dependent upon him, has given a great stimulus to industrial hygiene.

By a "workman" is meant "any person who has entered into a works under a contract of service or apprenticeship with an employer, whether by way of manual labour, clerical work, or otherwise."

Certain persons are outside the Act—*e.g.*, policemen, persons in the naval or military services, and non-manual workers where remuneration exceeds £250 a year.

A workman is entitled to compensation if he is incapacitated by a disease contracted in his trade, and due to his employment.

The following have been scheduled: Poisoning by nitro and amido derivatives of benzene or its sequelæ, carbon bisulphide or its sequelæ, nitrous fumes or sequelæ, nickel carbonyl or sequelæ; arsenic or sequelæ; lead, African boxwood or sequelæ; chrome ulceration or sequelæ, ulcerations produced by dust or caustic or corrosive liquids, chimney-sweep's cancer, cancer or ulceration of skin or of corneal surface of eye due to pitch, tar, or tarry compounds; nystagmus; glanders; compressed-air illness or its sequelæ; "beat" hand (subcutaneous cellulitis) of coal-miners, miners' "beat" knee and "beat" elbow, and inflammation of the synovial lining of the wrist-joint and tendon-sheaths of miners; ankylostomiasis; cataract in glass-workers; and telegraphists' cramp.

In the chapter on Vital Statistics, the method by which the effects of different occupation on disease are compared is

studied in detail. As causes of industrial diseases, Ogle mentions the following conditions:

1. Working in a cramped or constrained attitude.

2. Exposure to the action of special poisonous or irritating substances. The principal of these are scheduled in the Workmen's Compensation Act.

3. Excessive work, mental or physical.

4. Working in confined places in which the air is either initially foul or is likely to become so.

5. Excessive use of alcoholic beverages.

6. Liability to accident.

7. Exposure to inhalation of dust.

The inhalation of silica and steel-dust enfeebles the resisting-power of the lungs against the tubercle bacillus.

To these may be added:

8. Exposure to abnormal atmospheric pressure, as in Caisson Disease.

9. Exposure to the glare of molten glass—*e.g.*, Cataract in glass-workers.

10. Exposure to infection with certain animal and vegetable parasites—*e.g.*, *Ankylostoma duodenale, B. mallei,* and *B. anthracis.*

CHAPTER XV

COMMUNICABLE DISEASES

Smallpox, formerly one of the most prevalent and most dreaded of the infectious diseases, has now, thanks to the progress of medical science, been brought under control. It is world-wide in its distribution, but at the present time is endemic only in a few centres—*e.g.*, India, the Soudan, Central Africa, etc. The dark-skinned races are particularly susceptible to the disease. Smallpox in the course of a few years after its introduction into America by the Spaniards, carried off several millions of the native population.

The virus of the disease is probably ultra-microscopic, and is present in the vesicles and pustules, the desquamated epidermis, and probably in the mucus of the mouth, throat, and nose. Infection may be contracted by direct contact with a patient, or by means of clothing and other articles handled by him.

During an epidemic of Smallpox, the disease may be widely disseminated by persons having a mild attack which has not been diagnosed as Smallpox, the cases being often mistaken for Chicken-Pox; hence, during such an outbreak, it is advantageous to add Chicken-Pox to the list of Compulsory Notifiable Diseases.

The virus can resist desiccation for weeks, and on this account a house and its contents where a case has occurred must be thoroughly disinfected. The infective agent is probably conveyed through the air, and, according to some authorities, even long distances. Power, in 1884-85, believed that the incidence of the disease in houses grouped around the Fulham Smallpox Hospital could best be explained on the aërial convection theory, since the number of invaded houses in the circles, having the hospital as centre, diminished as the

length of the radius increased. Thus, with radii one-quarter, one-half, three-quarters, and one mile in length, the relative number of cases were 11, 3, 1·5, and 1 respectively. Investigations of outbreaks at Sheffield, Bradford, and Nottingham seemed to confirm this view, and within recent years an outbreak in Purfleet in Essex was believed by Thresh to find its readiest and most satisfactory explanation in the infection being conveyed aërially from the Metropolitan Smallpox Hospital Ships anchored in the Thames three-quarters of a mile off, which were in communication with the Kent, and not with the Essex shore. At the present time, the knowledge acquired with regard to the influence of "carriers" in the spread of other diseases makes us hesitate to accept the aërial convection theory, more especially as in certain outbreaks no undue prevalence of the disease occurred among the houses in the immediate vicinity of the hospitals.

Age influences markedly the incidence of and the mortality from the disease. In prevaccination days 90 per cent. of the mortality occurred during the first five years of life, and in unvaccinated communities the disease still shows the same disposition to attack the young.

Preventive Measures.—(1) Notification. (2) Isolation of the patient in a Smallpox hospital. According to a circular of the Local Government Board, such a hospital should be so situated that it would not have within a quarter of a mile of it as centre either a hospital, whether for infectious diseases or not, or a workhouse, or any similar establishment, or a population of 150 to 200 persons. In practice, it is very difficult to obtain such a site conveniently near a town. (3) Disinfection of the house from which the patient has been removed, and of every article, especially bedding and clothing in the house. (4) All who have been in contact with the patient should be traced, vaccinated, their clothing disinfected, and they should be kept in quarantine or at any rate under medical supervision for a fortnight. The usual incubation period of the disease is twelve days. (5) Since the diagnosis of the disease may be missed, it is important that Chicken-Pox should be made notifiable, and that the practitioners in the district should guard against being deceived by the scarlatiniform

and morbiliform rashes which sometimes precede the vesiculo-pustular eruption.

Vaccination.—The discovery of Jenner that inoculation with the matter taken from the vesicles of Vaccinia or Cowpox afforded protection against Smallpox has enabled civilized communities to drive the disease from their midst. Thus, in Prussia, where vaccination within two years of birth and revaccination at the twelfth year, and also on entering the army, is compulsory, not a single death from Smallpox has occurred in the Prussian Army from 1874 to the present time, and the decline of the incidence of the disease in Germany is far more marked than in countries where revaccination is not compulsory.

It has been definitely proved that Cowpox or Vaccinia is a form of Smallpox modified by passage through a different species of animal. It has been found possible to give rise to Cowpox in calves when Smallpox pustular matter is inoculated into one animal, and then matter from the site of inoculation injected into a second animal, and similarly from a second animal into a third. The lesions in the third animal have been found to correspond to those of Vaccinia, and their vesicular contents have caused successful vaccination of children.

No one who has approached the subject with an open mind can deny that vaccination protects against Smallpox; but some may doubt whether in these days of Public Health organization vaccination of the whole nation against Smallpox is necessary, when only a fraction of the population will ever be exposed to infection, and when warning of the outbreak of the disease can enable the unvaccinated to get vaccinated in time. At the present time, when people have no personal knowledge of the loathsome and fatal nature of Smallpox, and see in certain cases unpleasant symptoms arising from vaccination, it is not to be wondered at that an antivaccination cry has been raised, and that the law with regard to compulsory vaccination in this country has been somewhat relaxed in recent years.

When it is considered how extremely infectious the disease is, and how the virus clings for long periods to clothing, etc., and how modern rapid means of communication and travel

bring this country into contact with unvaccinated communities, it will appear that revaccination should be made compulsory rather than that children should be allowed to grow up unvaccinated. The history of vaccination in this country is briefly as follows: In 1796 Jenner introduced his discovery; in 1840 an Act was passed making vaccination gratuitous; and in 1854 vaccination was made compulsory, but this was only enforced after 1871 by the appointment of paid Public Vaccinators. By the Act of 1898 and 1907 greater liberty is given to the parent if he conscientiously believes that vaccination would be injurious to his child. The law at present requires that every child shall be vaccinated within six months of its birth, unless—(1) A medical certificate of postponement has been given on account of the occurrence of infectious disease in the house or neighbourhood, or on account of the condition of the child's health; (2) the child has passed through an attack of Smallpox, or unsuccessful attempts to vaccinate the child have been made on three separate occasions; or (3) the parents within four months of the birth send a statutory declaration to a magistrate that they believe vaccination would be injurious to the child. These Acts (1898 and 1907) containing clauses regarding " conscientious objectors " do not apply to Ireland. It is no longer necessary for the parent to take the child to the Public Vaccinator, whose duty it is, if required, to attend the child at home. An advantage of this arrangement is that there is no danger of Erysipelas or other infectious disease being contracted by the child when waiting with other children in a crowded dispensary.

Public Vaccinators are required to use only lymph supplied by the Local Government Board. This is calf lymph which has been proved by bacteriological examination to be free from pathogenic germs, glycerine having been added to it to accomplish this result. In its preparation the vesicles scraped from the abdomen of a calf which has been proved by veterinary examination to be free from disease, and which has been housed in hygienic surroundings, are made into a pulp, and mixed with five to eight times their bulk of 40 to 50 per cent. glycerine in water. In vaccinating, four separate good-sized vesicles not less than ½ inch from one another should be pro-

duced, and the total area of vesiculation resulting should not be less than ½ square inch.

Objection to vaccination is that it inflicts a certain amount of suffering on a child. This is admitted, but the evil resulting is insignificant compared with the gain. It is only where there has been some defect in the treatment of the vaccinated child that the ill-effects of vaccination, of which the antivaccinators make so much, result. Examples of such dangers and complications of vaccination are the following: (*a*) The lymph may contain the poison of Syphilis or Tubercle. When arm-to-arm vaccination was practised, in a few cases Syphilis was communicated in this way, but probably never Tuberculosis. The use of calf-lymph taken from a perfectly healthy animal removes this objection. (*b*) The lymph may contain streptococci and staphylococci, and give rise to Erysipelas and suppuration. Treatment of the lymph with glycerine has abolished this risk. (*c*) Spores of Tetanus may be present in the lymph, and vaccination may produce this disease in the child. This danger—and that it is a danger an epidemic of Tetanus (1902) produced in this way in the United States has made manifest—can be avoided by the hygienic housing and feeding of the calves, and by subjecting every sample of lymph put on the market to a most rigorous bacteriological examination. Glycerine does not kill Tetanus spores.

Value of Vaccination as a Protective against Smallpox.—In Jenner's time, inoculation of healthy individuals with pus taken from a Smallpox patient was freely practised. The inoculated suffered from an attack of the disease usually milder in form than that contracted in the natural way.

Inoculation for Smallpox was known in India long before the Christian era. The practice, which was introduced into England from Constantinople by Lady Mary Wortley Montague in 1717, was open to the following objections: (1) The person inoculated with Smallpox became a focus of infection for his neighbourhood; (2) fatal attacks of the disease sometimes resulted.

Jenner proved that vaccination with calf-lymph protects against Smallpox by vaccinating a number of persons, and then showing that on subsequent inoculation with Smallpox matter, they failed to develop the disease.

The countries of the world where vaccination is compulsory —*e.g.*, Germany, England—suffer far less from Smallpox than where the practice is neglected—*e.g.*, Italy, Austria. In an epidemic, the unvaccinated are attacked, whilst the vaccinated, living under the same sanitary conditions, escape. The same experience has been met with among the employees in Smallpox Hospitals. Vaccination does not protect indefinitely, but judging from the experience of Prussia, and especially that of the German Army, revaccination on a second or third occasion is sufficient to afford protection for life. If a vaccinated person contracts the disease, its character is determined by the time elapsing since vaccination, and by the efficiency with which the operation has been performed. Where there are several well-made cicatrices, the disease is milder than where there is a single mark. Statistics of every epidemic have proved the value of vaccination. Whitelegge, from an analysis of the figures supplied by Barry of the Sheffield epidemic of 1887-88, concludes "that the vaccinated part of the population had, as compared with the unvaccinated, at ages below ten years, a twenty-fold immunity from attack, and four-hundred-and-eighty-fold security against death from Smallpox; at ages above ten years, a five-fold immunity from attack, and fifty-one-fold security against death from Smallpox; at 'all ages,' a six-fold immunity from attack, and a sixty-four-fold security against death from Smallpox."

Varicella, or **Chicken-Pox,** is practically never fatal, and its only interest from the point of view of preventive medicine is that mild cases of Smallpox may, as already mentioned, be diagnosed as Chicken-Pox.

Scarlet Fever is a disease affecting especially children in temperate climates. The incubation period varies from twenty-four hours to seven days, but is usually three or four days. The onset is sudden, and is characterized by vomiting, fever, headache, sore throat, and the appearance of an erythematous rash within twenty-four hours. Recent experimental researches show that inoculation of material—*e.g.*, blood, emulsions of glands, tonsils, etc.—from scarlet fever patients into monkeys is followed sometimes by a morbid syndrome which resembles more or less that of Scarlet Fever in human beings.

The virus is probably filterable, and clings with great persistence to clothing and articles of furniture. Infection seems to be given off from the mouth and naso-pharynx, possibly also by the desquamated cuticle. Milk may act as a medium of infection, the virus probably in all cases being of human origin, although several outbreaks, notably that at Hendon in 1885, seemed to point to the cow as the source of infection. When convalescents from a fever hospital return home, fresh cases among their brothers or sisters or playmates sometimes occur. Such "return cases" are believed by Niven to be due to the recent association of the discharged patients with acute cases, and can be avoided by keeping the convalescents in separate wards, and systematically disinfecting their naso-pharynx for fourteen days before their discharge.

Preventive measures include notification of the disease, and suitable measures at the school attended by the child. Isolation should be for six weeks, and should be accompanied and followed by disinfection.

Measles is a world-wide disease, and although not considered as a serious one by the laity, registration returns show that of the common infectious diseases it is the one that causes most deaths. The immediate causes of death are usually Broncho-pneumonia, Diarrhœa, or Convulsions, following in the train of the disease. The incubation period is usually twelve days, and is followed by fever and by symptoms of a "cold"—Conjunctivitis and Bronchitis. The rash appears on the fourth day.

The experiments on monkeys conducted by Anderson and Goldberger have shown—(1) That the virus is present in blood, but only during the very early stages of the disease, before or shortly after the appearance of the eruption; (2) that the nasal and buccal secretions are infective, but that the infectivity is reduced, if not lost, with the approach of convaeslcence; (3) "scales" collected from human cases from four to seven days after the appearance of the eruption were non-infective. It is interesting to note that Koplik spots have been observed in monkeys experimentally infected with Measles.

Preventive Measures.—Since Measles is most infective during the early stages before the disease has been diagnosed, and

since the infectivity rapidly disappears, it is doubtful if any advantage commensurate with the expense would ensue by the addition of Measles to the list of Notifiable Diseases. It would probably be impossible to afford hospital treatment to all the cases notified. Hospital treatment undoubtedly would reduce the mortality, which is in the main due to Broncho-Pneumonia, and other complications resulting from improper nursing and neglect during convalescence. However, the function for which fever hospitals have been erected is to remove infective foci from the general community, not to relieve parents of the duty of taking proper care of their children. Probably the progress of school hygiene will in time prove effective in further reducing the mortality from Measles. "As a rule, Measles spreads only in infant classes, and only when 30 to 40 per cent. of the children are unprotected by previous attack. By means of 'measles registers' it is possible to determine the measles history of a class, and though it is impracticable to prevent the introduction of the disease to the school, it is possible to prevent the spread by closure or exclusion of unprotected children within nine to ten days of the first attendance of the initial case in an infectious state. If the lowest age-limit of school attendance were fixed at five years, the control of Measles would become more practicable, as children of a susceptible age would not then be brought so largely into the sphere of infection" (Whitelegge and Newman).

Whooping-Cough is second only to Measles as the most fatal zymotic disease. The incubation-period is probably more than one week. The disease is infectious, especially during its early catarrhal stages. A short Gram-negative bacillus, which in most of its characters resembles the *B. influenzæ*, and which was isolated by Bordet and Gengou in 1906, is now recognized as the infective agent. This bacillus is found in large masses between the cilia of the epithelial cells lining the trachea and bronchi. It seems to produce the symptoms partly by mechanical interference with normal ciliary action, and thus with the removal of secretion and of inhaled particles, and partly by the production of a mild toxin. The organism is most abundant at the early stages of the disease, and this is

in harmony with the clinical fact that the disease is most readily communicable at this stage. The disease is conveyed by particles of infected mucus from mouth and throat. The bacillus is very delicate, and it is therefore unlikely that fomites ever convey infection. The preventive measures are similar in the case of Measles and Whooping-Cough.

Influenza resembles Measles and Whooping-Cough in being so infectious at an early stage that, so far, preventive measures capable of controlling the spread of the disease have not been discovered. The disease is due to a small Gram-negative bacillus (Pfeiffer's bacillus), which grows best on media containing hæmoglobin. The bacillus readily dies out, so that clothing is unlikely to convey the disease. The bacillus is found in the nose, throat, and bronchi, so that infection is acquired by inhalation. The disease frequently occurs in pandemic form, and although not often directly fatal, except in the case of the old and feeble, it causes a high mortality by respiratory and cardiac complications. During an epidemic, old people should avoid travelling or attending meetings.

Pneumonia is second only to Tuberculosis as a cause of death in the United Kingdom. In 1911, 37,642 deaths were attributed to this disease. As well as being a direct cause of death, Pneumonia is a frequent complication of other diseases—*e.g.*, Measles, Whooping-Cough, Influenza. In the great majority of cases the infective agent is the capsulated lanceolate Gram-positive diplococcus of Fraenkel. This micro-organism is frequently found in the throat of healthy persons, but there is evidence that the strains isolated from cases of Pneumonia and from persons in contact with them are more virulent than the normal saprophytes of the throat.

Predisposing conditions of infection are chills following exposure to inclement weather. The greatest prevalence of Pneumonia occurs at the season of most rapid and sudden changes of the temperature, which is most often in the early spring, but may be in winter. Weakening of the system by malnutrition, alcoholism, and by the poison of various diseases favours the development of Pneumonia. The lowering of the resistance of the individual is probably a more important factor than the presence in the throat of the infective agent in the

etiology of the disease; still, in view of the difference in virulence of the strains of the Pneumococcus, it is rational to use disinfectants against the germs present in the patient's mouth and in those of his immediate attendants.

Cerebro-Spinal Fever.—Epidemics of this form of Meningitis occur from time to time in certain centres. In 1907-08 an epidemic occurred in Belfast, and about the same time in Glasgow. The specific cause of the disease is the *Diplococcus intracellularis meningitidis* (Weichselbaum), which is found in the cerebro-spinal fluid, nasal and buccal mucous membranes, and in certain cases in the blood. This micro-organism is Gram-negative, and closely resembles the gonococcus in most of its characters. Of a large number of sugars and alcohols examined by the writer, the only two fermented by it were glucose and maltose. The gonococcus does not ferment maltose as a rule. The blood-serum of patients contains a high content of specific opsonins and agglutinins. The micro-organism grows best on media containing ascitic fluid, and requires frequent transplantation to keep it alive. The diplococcus is found often in the throats of healthy "contacts," and no doubt such carriers are instrumental in spreading the disease. The majority of the cases are children and young adults. The disease is probably conveyed by the inhalation of particles of infected mucus derived from the throats of patients and contacts. The preventive measures are notification, isolation, and the use of antiseptic throat sprays and tablets.

Poliomyelitis.—This disease, also known as **Infantile Paralysis,** is characterized by lesions of the anterior horns of the spinal cord, resulting in paralysis of various limb muscles. Sporadic cases of the disease are met with from time to time, but occasionally epidemics occur on an extensive scale. The infective nature of the disease is now recognized. The virus, which is filterable, has been found in the spinal cord, and in washings from the nasal, buccal, and intestinal mucous membranes. The virus has been found in the tonsils six months after the onset of the disease. Important light was thrown on the means by which the disease is conveyed by the discovery of the virus in the throats of healthy contacts. The virus can

resist the effects of desiccation for prolonged periods (at least twenty-eight days), and may possibly be conveyed by infected dust and clothing, as well as by moist particles of mucus from the mouth. Rosenau showed that in a certain proportion of cases the disease could be transmitted from sick to healthy monkeys by the bite of the stable-fly.

Flexner and Noguchi have recently obtained cultures, and have been able to produce typical Poliomyelitis in monkeys by inoculation with the twentieth generation of cultures from the original infected animal. The micro-organism described by these workers consists of globoid bodies of extremely small size arranged in pairs, chains, and masses.

Preventive measures include notification, isolation of patient, and, if possible, of contacts—at any rate, children from infected households must be excluded from school—disinfection of nasal fossæ, and the prophylactic administration of urotropine to contacts, resulting in the appearance of formic aldehyde in the cerebro-spinal fluid. It has been shown that the administration of this drug to monkeys prevents the development of experimental Poliomyelitis.

Diphtheria is characterized by a membranous inflammation, usually of the nose, tonsil, and pharynx, produced by a definite germ—the Klebs-Loeffler bacillus. Among the characters by which this bacillus is recognized are—(1) Its morphology and staining properties (it is Gram-positive, and shows in staining by Neisser's method metachromatic granules); (2) rapid growth on serum, and acid production in media containing glucose; (3) pathogenicity for guinea-pigs; (4) the production of a toxin which can be neutralized by an antitoxin. The diagnosis of the disease is facilitated by the bacteriological examination of throat "swabs."

In 86 per cent. of the cases the bacilli disappear from the throat within seven days after the separation of the membrane. A few convalescents, "chronic carriers," may harbour the germs for months, or even a year or more. A "carrier" examined by the writer communicated the disease a year after her own attack.

Diphtheria, at one time relatively a rural disease, is now more common in urban districts. Schools, by bringing children

into close association, play an important rôle in the dissemination of the disease. The exchange of pencils, toys, and sweets —and these too often are smeared with the scholar's saliva— no doubt helps to convey infection. The inhalation of infected droplets of mucus sprayed out into the air by the children in singing, talking, coughing, and sneezing, is probably the commonest method of acquiring the disease.

Dampness and insanitary conditions of the home are predisposing causes. Milk infected from human carriers has been responsible for numerous epidemics. Diphtheria is most commonly a disease of childhood, only 3·5 per cent. of the deaths occurring at ages over fifteen. The incubation period is usually three or four days.

Preventive Measures.—In addition to the usual notification, isolation, and disinfection, it is necessary to take the following precautions: Before the child is allowed to return to school, cultures of swabs taken from its throat should on at least two occasions have been negative. No child from an infected household should be allowed to attend school. In certain cases swabs should be taken from all connected with the house —*e.g.*, in the case of teachers and milkmen, and if there is a suspicion that a member of the family is a carrier. Where there is a strong suspicion that a milk-supply is responsible for the disease, steps should be taken to test this suspicion, and if a *prima facie* case is made out, the milk-supply should be at once stopped.

Susceptible contacts should be kept under supervision, and on the first appearance of a suspicious sore throat a full dose of antitoxin should be given. In view of the danger of anaphylaxis, it is probably better not to give antitoxin to contacts as a routine prophylactic measure. Defective drains should be remedied.

Erysipelas is a spreading inflammation of the skin and lymphatics due to infection with streptococci. Before the antiseptic era it worked fearful havoc in surgical and maternity wards.

Puerperal Fever.—In 1911 the number of deaths attributed to this cause in England was 1,262, corresponding to a rate of 1·4 per 1,000 births. The total number of deaths assigned to

pregnancy or childbirth was 3,413, corresponding to a rate of 3·87 per 1,000 births. The preventive measures are the practice of antiseptic midwifery.

Enteric Fever.—In this disease the chief lesions are in the intestine. The name Typhoid Fever is used as synonymous with Enteric Fever, but it would be well to restrict the term Typhoid Fever to cases proved by bacteriological examination to be infected with the *B. typhosus*, whilst the term Enteric Fever would include not only these, but also cases of infection with paratyphoid bacilli (Paratyphoid Fever).

Etiology.—The *B. typhosus* is an actively motile bacillus in many respects resembling the *B. coli communis*, but differing from it in not forming gas in carbohydrate media, and in not forming indol. In isolating the bacillus, use is made of media containing bile salt and various coal-tar dyes—*e.g.*, malachite green, brilliant green, etc. The typhoid bacillus is present in the stools of all cases at some stage of the disease, and is found in the urine of 30 per cent., especially in the later stages of the illness.

Typhoid Fever is essentially a disease of early adult life, but an attack may occur at any age. The mortality is usually about 10 per cent., so that the morbidity-rate is very much higher than the death-rate.

Season.—The number of cases increases during August and September, to reach a maximum in October or beginning of November, after which there is a gradual decline.

The infective agent in Enteric Fever is swallowed, and may be contained in water, milk, cream, ice-cream, meat, and other food, vegetables, and shellfish. The exercise of strict cleanliness in the handling of food and drink, and the collection of these from pure sources of supply, is essential to the prevention of the disease. The occurrence of Enteric Fever indicates that material derived from the intestinal or urinary tract of another individual has been taken into the mouth. The wide prevalence of Enteric Fever in a town shows a neglect of personal hygiene and municipal sanitation. Infection may occur through want of care in disposal of the excreta of a patient suffering from this disease, and also from the contamination of food by "carriers." The latter, not being confined to bed,

are able to infect not only their own household, but many others. Probably at least 3 per cent. of convalescents from Enteric Fever continue to harbour the specific germ, and discharge it continuously or intermittently in their stools or urine. In "carriers," the nidus of infection seems to be the gall-bladder and bile-ducts. Carriers frequently have bilious attacks accompanied by jaundice. Such was the history in two out of three outbreaks of Enteric Fever (due to carriers) investigated by the writer. In all three cases the carriers were women. The following notes supplied by Dr. R. C. Miller, Dervock, Co. Antrim, give an idea of the dangers of a carrier to her associates: In 1905 in a farmhouse three members of the family and the servant-boy suffered from Typhoid Fever about the same time, the servant-boy being first attacked. One of the patients was an old woman seventy-three years of age, and that she was the source of infection of the subsequent cases is probable, since typhoid bacilli were found in her stools in 1913. In 1907, 1911, and 1913, a servant-boy on this farm developed Typhoid Fever, and in 1909 a girl who resided close to the farm, and who was frequently in the house. In 1911 a servant-girl, who, though not hired on the farm, almost certainly contracted Typhoid Fever there, and, when sickening, returned to her own home, where she infected five members of her family.

Of the usual media of infection, milk allows the bacilli to rapidly multiply, whilst in water their number rapidly diminishes. After large numbers of typhoid bacilli present in the urine of a typhoid carrier had been added to water, the latest time on which their isolation was possible was twenty-three days after the addition. It is probable that in a month typhoid bacilli completely disappear from infected water. Where a water and milk supply cause an outbreak of Typhoid Fever, the latter is of an explosive character—*i.e.*, a large number of cases occur almost simultaneously. Where sporadic cases occur, the disease is usually due to contact with a patient or carrier. The importance of shellfish in typhoid dissemination has already been alluded to in the chapter on Food. Since the prohibition of the sale of cockles gathered from the polluted foreshore of Belfast Lough, there has been a great decline in

the incidence of Typhoid Fever in Belfast. In instances where young adults are exposed to risk of infection, the prophylactic use of a vaccine is advisable. The vaccine used in the British Army consists of a broth culture sterilized by heating to 53° C. for one hour. A dose of 500,000,000 bacilli is given, followed ten days later by one of 1,000,000,000. The following figures, as supplied by Leishman, show the benefits of inoculation in twenty-four units of the British Army sent out to India. The average length of the period on which the observations were based was eighteen months:

Total Number of Soldiers under Observation.	Number of Inoculated.	Number of Uninoculated.	Case Incidence per 1,000.		Case Mortality per 1,000.	
			Inoculated.	Uninoculated.	Inoculated.	Uninoculated.
19,314	10,378	8,936	5·39	30·4	8·9	16·9

In round numbers, a person who has been inoculated is almost ten times less likely to die from Typhoid Fever than an uninoculated person living under the same conditions.

Preventive measures include the securing of pure water, pure food, and pure air. The latter will involve the maintenance of sanitary fixtures in good order, so as to prevent effluvia. A most important general measure is the rapid removal of excreta from the premises. Water-closets should, where possible, be substituted for privies and earth-closets. Where the latter are used, access of flies to the excreta should be prevented. Special measures are the notification of the disease, isolation, and disinfection. An attempt should be made in every case to trace the source of infection, and this will involve in many cases the search for a "carrier."

Epidemic Diarrhœa is one of the most frequent causes of death, especially of children under two years of age. A large but varying amount of infant mortality is due to it. In 1912 Diarrhœa and Enteritis caused 28 per cent. of the total infantile mortality, whereas in 1910, when the summer was cool and wet, the proportion so caused was only 12 per cent. There are many conditions which predispose to Diarrhœa. Among these may be mentioned season of the year, pollution of the

soil, overcrowding and the defective hygiene this condition implies, and contaminated milk. With the mother, and her opportunities for giving the child proper care, rest in large measure the chances of a child escaping the disease. The mortality from this disease among breast-fed children is only a fraction of that met with among bottle-fed babies. In this country the mortality-curve rises rapidly in July, and reaches a maximum early in August, after which it steadily declines throughout August, September, and October. Ballard found that this summer rise of diarrhœal mortality commenced when the 4-foot earth thermometer reached 56° F., and that the maximum diarrhœal mortality is usually attained in the week in which the temperature recorded by the 4-foot earth thermometer attained its weekly maximum. There is no doubt that temperature is the greatest factor in the production of the disease, but probably the temperature of the soil is only an index of the temperature of the air in rooms in which milk is stored which is most favourable to the infective agent. There is little doubt that the disease is due to a poison developed by bacteria either in the food before being swallowed or in the alimentary canal. In America a species of Dysentery bacillus seems to be the specific cause, but in England this has seldom been met with in Infantile Diarrhœa, though it has been found in asylum Dysentery in this country. French observers incriminate the *B. proteus*. Flies probably are the agents by which in many cases the infective agent is conveyed from filth to the food. The chief preventive measure is care in the feeding of the child. This will involve delaying weaning until the heat of summer is over, or in the case of a bottle-fed child in the thorough cleansing of the bottle and the pasteurization of the milk. The milk should be stored in a cool place, and should be protected from flies and dust.

Typhus Fever formerly caused a very high mortality, especially among people living under very unhygienic conditions, such as were once common among prisoners, sailors, and soldiers. Cases of Typhus are still frequently met with in Ireland and Russia. The last general epidemic of the disease occurred to Ireland in 1862-1864. The conditions which predispose in Typhus are overcrowding, filth, and privation. The incuba-

tion period is usually twelve days, and the mortality from the disease increases from childhood to later middle life. The following facts with regard to the etiology of the disease have now been established: (1) The virus is present in the blood, but apparently not in the buccal and pharyngeal secretions. (2) Monkeys can be infected not only by inoculation with the blood, but also by the bites of body-lice taken from patients or from infected animals. It is probable that lice are always concerned in the transmission of the disease. (3) So far the virus has not been obtained in culture. The demonstration that Brill's Disease was really a mild form of Typhus has discovered the missing epidemiological link between sporadic cases and outbreaks. In the propagation of Typhus this mild form plays somewhat the same rôle that the "missed" or the "carrier" cases do in such diseases as Diphtheria and Typhoid. The great preventive measure is attention to personal hygiene. Contacts must be traced and kept under medical observation for a fortnight. Such persons must be cleansed and freed from vermin, and their homes and clothing disinfected.

Tuberculosis.—In this disease, which is common to man and the lower animals, various organs of the body are attacked. In adults the common form of the disease is Pulmonary Tuberculosis, or Phthisis, whereas in children the lymphatic glands, especially of the abdomen and neck, and the bones and joints, are most frequently involved. The disease has acquired its name from the presence in the lesions of small greyish masses of cells (tubercles). Koch's discovery (1882) in tubercular lesions of characteristic bacilli complying with all the postulates required to establish their etiological significance created a revolution in medical thought. Tubercles consist of blood and tissue cells which have proliferated in response to the irritation set up by the presence of Koch's bacillus. The tubercle bacillus possesses the following characteristics: (1) It is acid-fast—*i.e.*, when stained with a strong dye, such as carbol-fuchsin, subsequent washing of the slide with strong solution of mineral acids is unable to remove the stain from the body of the bacillus. This property, which is also possessed by the *B. lepræ* and a considerable number of saprophytic bacteria, is due to a waxy sheath which prevents the

acid reaching the dye. This waxy envelope also enables the bacillus to resist the action of various chemicals and the process of desiccation, so that dust derived from floors soiled with tubercular sputum may contain living bacilli. (2) Growth is slow, and occurs only at body temperature. Blood-serum, glycerine agar, and egg media are used for its cultivation.

There are at least three varieties of the bacillus—the *Typus humanus*, *T. bovinus*, and *T. avium*, so called from their presence in the lesions of men, cattle, and birds.

Prevalence.—In the British Isles some 60,000 deaths annually are due to Tuberculosis, the disease being the cause of about one-tenth of the whole mortality. During the last half-century there has been a decline amounting to 50 per cent. in the tubercular death-rate in England, but in Ireland the disease is as prevalent to-day as it was fifty years ago. It is now beginning to show a slight decrease, due no doubt in part to the work of the Women's National Health Association.

The age of maximum mortality from Phthisis at the present time is forty-five to fifty-five years for males, and thirty-five to forty-five for females. Formerly the maximum mortality occurred among younger individuals. It may be that improved conditions of life have enabled the weaker part of the population to survive a further decennium.

CAUSES OF PREVALENCE—1. Direct Cause.—The inhalation or ingestion of tubercle bacilli by a susceptible individual. Medical opinion is divided as to the route by which the tubercle bacillus commonly enters the body—by the respiratory or alimentary tract. The view which was universally held until recent years, and which found in Koch a stanch supporter, is that in Phthisis the bacilli are inhaled and reach the lung directly from the air passages. Behring, Calmette, Whitla, and Symmers and others, believe that the bacilli are swallowed and enter the system through the lymph vessels, the portals of entry being the tonsils, pharynx, and intestine. According to this view, the lungs are reached by bacilli from the bronchial glands, the latter having been infected from the cervical or mesenteric chains. It is probable that infection by both routes occurs. In the case of adults, the aërogenic path is the usual one, whilst in children under five years of age

entrance by the alimentary canal is of frequent occurrence. The bacilli can pass through the intestinal mucous membrane without causing ulceration or other evidence of their passage. Flügge has shown that guinea-pigs can be infected both by inhaling and by swallowing tubercle bacilli, but that the effective dose required by the alimentary route is several thousand times larger than that required when the bacilli enter by the respiratory tract.

Bacilli may reach the lungs (1) by being contained in dust derived from ground contaminated with tubercular sputum; (2) through the medium of droplets of mucus sprayed into the air by a phthisical patient in the act of coughing, sneezing, talking, etc. Flügge found that such droplets were abundant within 50 centimetres of the mouth, but rare at distances greater than 1½ metres.

Tubercle bacilli that are inhaled by man are in the majority of cases derived from a human subject, whilst those that are swallowed may be of human origin, or may be contained in tuberculous milk and meat.

Bovine and Human Tuberculosis.—Up to 1901, when Koch at the London Congress on Tuberculosis made his famous pronouncement, the danger of tubercular cattle to man was exaggerated. Koch's experimental work led him to the conclusion that the differences in infectivity of human and bovine tubercle bacilli was so great that it was unnecessary for Sanitary Authorities to take precaution against bovine infection. Such a statement, coming from so distinguished an authority, caused investigations on the matter to be made in almost every civilized country. The following facts seem to have emerged:

(1) That the bovine type can be readily distinguished from the human type by—(*a*) Being more pathogenic to rabbits, and by giving rise to progressive Tuberculosis in cattle. Cattle can be infected by the human type, but the lesions are limited in extent, and large doses are required. (*b*) Being more difficult to cultivate, and the growth less profuse. (*c*) The difference in reaction of glycerine broth produced by its growth in this medium.

(2) That in practically all cases of Pulmonary Tuberculosis in the adult it is the human type that is found.

(3) That in cases of Surgical Tuberculosis infection may be due to bacilli of either type. In Tubercular Adenitis and Abdominal Tuberculosis occurring in children under five years more than 50 per cent. of the cases show bovine bacilli.

It would seem to be definitely established that in the case of Pulmonary Tuberculosis the phthisical patient is the *fons et origo* of infection, and that in Tuberculosis of children cow's milk is often the infective medium. About 10 per cent. of milk samples examined contain tubercle bacilli. It has been suggested that the human type of bacillus may be derived from a bovine strain which has become altered by residence in a different host. There is practically no experimental evidence in support of this view.

2. **Accessory Causes.**—Conditions lowering the vitality of the patient's tissues: (*a*) Insufficient or unsuitable food. (*b*) Acute exanthemata. Tuberculosis is often a sequela of Measles and Whooping-Cough. (*c*) Injury of the lung produced by the inhalation of mineral or organic dust—*e.g.*, silica, iron, and steel particles, flax fibres, etc. (*d*) Dampness of the dwelling, causing Catarrhs and wasteful loss of heat from the body. (*e*) The breathing of a vitiated atmosphere. The importance of open windows in bedrooms is not generally appreciated. The poor, insufficiently clad, inadequately fed, trying to keep warmth in their bodies, close up every fresh-air inlet in their overcrowded sleeping-rooms. (*f*) Inherited susceptibility to attack by the tubercle bacillus. This, though mentioned last, is by no means the least important accessory cause of Tuberculosis. Post-mortem examinations of the bodies of individuals over forty years of age who have died from other diseases show in a great majority of the cases evidence of old latent or healed Tuberculosis. The tubercle bacillus is so widely diffused that few have not taken it into their bodies at some time or other, but the resistance offered by the defensive mechanism of the body in the majority of the population is sufficient to disarm it. That heredity is an important factor in determining whether clinical Tuberculosis will result from the introduction of the bacilli into the system is a fact familiar to most observers. It must be borne in mind that the occurrence of one case in a family exposes the other members (if care is not

taken) to the risk of massive doses of the bacilli, and we know from animal experimentation that the size of the dose and the frequency with which it is repeated are important points in determining an infection.

Preventive Measures.—(1) Notification of the disease to the Sanitary Authority. This is now compulsory in all cases in England, and in cases of "open Tuberculosis" in Ireland.

(2) Disinfection of sputum and of houses occupied by consumptives. Instructing the patient to hold a handkerchief over his mouth when coughing. Preventing of spitting on the floor of rooms and public conveyances.

(3) The supply of non-tuberculous milk and meat.

(4) The amelioration or removal of those conditions mentioned under the Accessory Causes of the disease.

(5) Free examination for the tubercle bacillus by the Sanitary Authority of sputum of suspected cases, and of milk.

(6) Establishment of tuberculosis dispensaries and sanatoria. At the dispensary cases are diagnosed, and suitable treatment advised. At the same time, the homes are visited and the other members of the family examined. In this way incipient cases may be detected, and attention may be called to housing defects. In the Sanatoria cases detected early may recover, and those that are too far advanced for this to be attained are segregated and an infective focus removed from the midst of their families. Patients who have recovered or improved on leaving the sanatorium and returning to their families are able to carry out the precautions necessary to render them innocuous to those with whom they are brought into contact. The educational effect of sanatorium treatment is no less important than its therapeutic.

The provision for the treatment and prevention of Tuberculosis included in the National Insurance Act emphasizes the fact that this is not merely a problem of medical, but also of social science. It is to be hoped that the work now undertaken by the Sanitary Authorities against this disease will eventually result in its eradication.

Hydrophobia, or **Rabies,** a disease usually communicated to man by the bite of a rabid dog, has since 1902 been absent from the United Kingdom. This result has been obtained by

the enforcement of the Rabies Order and of the Importation of Dogs Order issued by the English Board of Agriculture. The object of these Orders was the compulsory muzzling of dogs, and what amounted to the practical prohibition of the introduction of dogs from abroad. Statistics show that 15 per cent. of people bitten by rabid dogs contract the disease, and that practically all die. By Pasteur's method of treatment by inoculation with emulsions of the dried cords of rabid rabbits, the liability of the person bitten to die has been reduced fifty to one hundredfold. The long incubation period of the disease—forty days usually—allows the preventive treatment to be adopted in time. The virus is filterable, and recently cultures have been obtained by Flexner and Noguchi.

Glanders is mainly a disease of horses, but occasionally man is infected from the horse, and the disease thus acquired is generally fatal. In the horse there is ulceration of the nasal mucous membrane and enlargement of lymphatic glands (farcy buds). The infective micro-organism is the *B. mallei*, which in broth culture forms a filterable toxin—mallein—injection of which into an infected animal leads to a swelling at the site of inoculation and to a rise of temperature. Mallein is therefore useful for diagnostic purposes.

The chief preventive measure is the enforcement of the Glanders and Farcy Order (1907) issued by the Board of Agriculture. This provides for the notification of the disease to a veterinary inspector, slaughtering of diseased horses, disinfection of stables, etc.

Tetanus, or **Lock-Jaw,** often affects horses, and man not infrequently contracts the disease, usually from infection of wounds with the specific germ—the *B. tetani*. This bacillus is found in garden earth and street-sweepings, which probably acquire the germ from horse-dung, the *B. tetani* being a common inhabitant of the horse's intestine. The *B. tetani* is an obligatory anaërobe which remains localized in the wound, and there manufactures a toxin which travels up the lymph sheaths of the motor nerves, and irritates the motor cells of the spinal cord.

The preventive measures are the antiseptic treatment of wounds, and in certain cases the use of antitetanic serum.

Since the use of antitetanic serum as a preventive measure, far fewer cases of Tetanus now occur as the result of wounds sustained by the use of fireworks at the Fourth of July Day celebrations in the United States of America.

Anthrax.—This disease is common to man and the majority of the domestic animals. Pasteur and Koch's study of the *B. anthracis* laid the foundation of modern bacteriology. The *B. anthracis* is a large Gram-positive non-motile bacillus, which forms large round or oval spores. The spores can resist desiccation for years. There are two principal forms of the disease: (1) External malignant pustule at site of inoculation; (2) septicæmia arising from the infection entering through the respiratory or intestinal mucous membranes. The disease is contracted usually by butchers and those engaged in handling hides, and also by wool-sorters.

The prevention of the disease in animals and man is aimed at by the Anthrax Order of 1899 issued by the Board of Agriculture. This provides for the isolation of the infected animal, the disinfection of premises, and the safe disposal of the carcass.

The prevention of Wool-Sorters' Disease consists in the carrying out of the provisions of the Home Office Order (1905) dealing with the subject. These include (1) the steeping of bales of hair and wool in water before opening them in order to abate the dust; (2) the use of exhaust draughts at the working-benches to convey away the dust into a special collecting-room, where it can be afterwards precipitated by a jet of steam, and then collected and burned; (3) the wearing of overalls by employees; (4) the free use of disinfectants; (5) the prohibition of meals in the sorting-rooms, and the cleansing of the hands before eating; (6) the prevention of men with open sores engaging in the work of the sorting-room. Cases of Anthrax are notifiable to the Home Secretary, as are also cases of poisoning by lead, arsenic, phosphorus, and mercury.

Syphilis would appear at first sight from an examination of the Registrar-General's Returns to be an infrequent cause of death, since only 1,856 deaths are attributed to it during 1911, and of these, more than half were children under one year of age. It is probable that this figure does not represent more than one-quarter of the mortality caused by the *Spirochæta*

pallida, which is now recognized as the infective agent. When it is remembered that practically all cases of General Paralysis of the Insane and of Locomotor Ataxia are syphilitic in origin, and that in a very considerable proportion of other forms of nervous disease and in many cases of Aneurism and Arterial Disease Syphilis is an important predisposing factor, Osler's calculation that the disease is responsible for 7,000 deaths in Great Britain annually is not an overestimate. As a cause of abortion and miscarriage, Syphilis takes first place, and of this effect the Death Returns take no notice, since still-births are not registered.

The prevention of Syphilis and other forms of Venereal Disease in this country is exceedingly difficult, since many regard the taking of preventive measures as countenancing vice. The interest of innocent women and children, however, demands that an attempt should be made to remove this dark blot from our civilization. Prevention of this mortality will include payment by the State to enable the disease to be recognized at an early stage. Under such heading we may put the use of the microscope and of the Wassermann reaction. The rapid spirillicidal effect possessed by Ehrlich's Salvarsan will render practicable the question of dealing with " carriers " of the disease.

Instruction with regard to the dangers of the disease should be imparted to every boy at puberty.

Somewhat similar measures will be required to prevent the ravages of the gonococcus, which is responsible not merely for **Gonorrhœa,** but for its serious complications—*e.g.*, Prostatis, Epididymitis, Cystitis, Conjunctivitis, and Stricture in the male, and for Endometritis and Salpingitis in the female. To the gonoccocus also is attributable a considerable proportion of the cases of sterility.

Contagious Ophthalmia.—Under this heading two distinct diseases are considered—(1) Trachoma; (2) Ophthalmia Neonatorum. The infective agent in Trachoma is still uncertain. The disease is very chronic, and the complications numerous. The seriousness of Trachoma has long been recognized in the United States, which forbids the landing of any passenger suffering from the disease.

Ophthalmia Neonatorum is caused by introduction of infective matter into the eyes of the child during its birth. In the largest number of cases the gonococcus is the microbe concerned. The Royal Commission on Blind, Deaf, and Dumb, estimated that in 1889 there were 7,000 persons blind from Ophthalmia Neonatorum in the United Kingdom. This condition is productive of about one-tenth of all cases of blindness and for at least one-third of the blindness in inmates of British Blind Schools.

The prevention of Contagious Ophthalmia involves the notification of the disease. At the present time Ophthalmia Neonatorum is among the diseases which are compulsorily notifiable in England. The use of the same towel by several people is instrumental in spreading both diseases, particularly Trachoma. The enforcement of the rules of the Central Midwives Board and of the Notification of Births Act, 1907, should lead to the disappearance of Ophthalmia Neonatorum. The midwife is required, as soon as the child's head is born, and if possible before the eyes are opened, to carefully clean the eyelids with clear lukewarm water. If inflammation of the eyes occurs, the midwife must seek medical help. The instillation of a dilute solution of silver nitrate into the eyes of the new-born child (Crede's method) has proved an effective measure in maternity hospitals.

CHAPTER XVI

TROPICAL DISEASES

Malaria.—Malarial fevers are widespread throughout the temperate and tropical regions of the world. Broadly speaking, the higher the temperature and the moister the atmosphere, the greater is the prevalence and the severer is the type of the disease. The disease is rarely seen in cold climates, and never above the latitude of 60 degrees North. Along the banks of rivers and in marshy regions the incidence of the disease is greatest. From time immemorial the miasma, or mist rising from swamps, has been accredited with causing the disease. It was only the researches of Ross and others, at the end of the nineteenth century, that demonstrated how these conditions favoured the endemic existence of Malaria in certain localities. In 1880 Laveran discovered in the red cells of the blood of a malarial soldier bodies which are now recognized as the infecting parasite. This discovery, however, attracted little attention at the time, and it was only after the demonstration by Ross of the agency of mosquitoes in the transmission of Malaria, in the years 1897 to 1899, that a satisfactory explanation was afforded of the reason why certain definite conditions were necessary for the existence of the disease. Thus, heat and moisture are favourable to the development and activity of Anophelinæ—a family of mosquitoes concerned in the transmission of the parasites.

There are several clinical varieties recognized, each of them due to infection with a special form of parasite. Laveran's germ, *Plasmodium malariæ,* is a protozoon belonging to the class Sporozoa, and has a very complicated life-history, one phase of it being passed in the blood of man, who is the intermediate host, the other in the body of Anopheles, which is the definitive host.

When an infected mosquito bites a susceptible individual, it introduces into the blood a thin fusiform body, called a sporozoite. This is the infecting agent of the disease. The sporozoites enter the red cells, increase in size until they occupy from one-third to the entire area of the cell. Then radial segmentation into six or twelve wedge-shaped bodies, called "sporocytes," occurs, which are set free into the plasma on the rupture of the red cell. The sporocytes attack other red cells, and the same process is repeated indefinitely. Certain of the fully developed plasmodia do not sporulate, but increase in size, and in certain instances become crescent-shaped; they represent sexual elements. These gametocytes, while confined to the blood, undergo no further development; but when taken into the stomach of a mosquito, flagella-like bodies are detached from the male element (the microgametocyte), one of which enters and fertilizes a female gamete (macrogametocyte), which, now known as a zygote, or travelling vermicule, burrows its way along the muscular fibres of the stomach wall and forms there a cyst (oocyst), in which the spores, or sporozoites, are developed. On about the twelfth day, the sporozoites are discharged into the body cavity, from whence they make their way to the salivary glands of the insect, and are there ready to be inoculated into the body of an animal bitten by the mosquito.

The oocysts grow best at temperatures from 20° to 30° C., and are killed at temperatures steadily under 16° C.—a fact which largely accounts for the geographical distribution of the disease. There are very many species of anopheles which can act as hosts for the parasite, of which, perhaps, the *Anopheles maculipennis* is the best known. An anopheles has palpæ the same length as the proboscis, is dapple-winged, and its body is not parallel to the surface on which it rests, as in the case of culex, but forms an angle with it.

Conditions influencing the Incidence of Malaria—(1) **Season.** The disease is most prevalent in temperate climates during the warm season, and in the tropics during the wet season. Cold weather and frosts cut short an epidemic. (2) **Age.**—Children are more susceptible than adults. (3) **Race.**—Negroes possess a certain degree of immunity, which is probably in part acquired

as the result of infection in childhood, but also natural, since the susceptibility of the black man in America is only about one-third that of the white. (4) **Occupation.**—The anopheles breed well in pools of water in the country; hence workers in swampy rice-fields are frequently attacked.

Preventive Measures.—Theoretically, the simplest method of stamping out Malaria in a district would be the isolation of the patient and his protection from mosquito bites, so that in time the insects would have no source of acquiring infective properties. However, it is found that in such regions many people following their usual avocations, and especially children, have parasites in their blood. To deal with these parasites, a continued course of treatment with quinine is most effective; but since the cinchonization has to be assiduously continued for several months, and since it is difficult to effect this when dealing with the native population, the method has not obtained the success anticipated for it. At the same time, the prophylactic use of quinine by new arrivals in an infected district is very effective, since the plasmodia are in this way killed during their incubation period.

Some authorities prescribe 5 grains three times a week, others 15 grains once a week. The second course is to obtain protection from mosquito bites—(*a*) By mechanical means—*e.g.*, the use of mosquito curtains, gaiters, and gloves, and the screening of buildings; (*b*) the reduction of mosquitoes by the destruction of their breeding-ground. This may be effected by the filling up of pools, ponds, and marshes, and by drainage by means of a series of agricultural drains.

In every locality the habits and life-history of the particular species of anopheles responsible for the spread of the disease must be studied, and the preventive measures based on the knowledge acquired. Thus, at Klang, in the Malay Peninsula, the removal of jungle and the establishment of a system of open agricultural drains eradicated malaria, since the mosquito in question did not breed in running water; while it has been found that the malaria present in the ravines above the town is conveyed by a mosquito whose eggs, larvæ, and nymphæ develop in running streams, and in this case the covering over of the watercourses is the measure indicated. Where sheets of water

cannot be drained, the covering of the surface by a film of oil serves for the destruction of the larvæ in the water by preventing them from obtaining air. In every district there should be a staff of inspectors to see that water-butts, empty tins and cans, do not form a nidus for hatching the eggs of Anophelinæ. The remarkable results obtained at Ismailia, on the Suez Canal, at Klang and Port Swettenham in the Malay Peninsula, as well as by the Americans at Havana and Panama, show that a campaign rigorously conducted against mosquitoes can in great measure prevent the epidemic spread of the disease.

Blackwater Fever.—This disease has a geographical distribution similar to that of Malaria, and is especially frequent on the West Coast of Africa. By many it is regarded as malarial in nature, whilst others believe that a different protozoon parasite is responsible. As the name implies, the urine is dark in colour, the pigment being altered hæmoglobin. Some authorities hold that the hæmoglobinuria and other symptoms of the disease are due to the action of the quinine administered to the case. The disease is exceedingly fatal, and the preventive measures to be adopted are along the same lines as those in the case of Malaria.

Yellow Fever.—As in the case of Malaria, the geographical distribution of this disease is determined by the requirements of the particular mosquito now recognized as the vector of infection. Yellow Fever is endemic in three centres—(1) The West Indies and the adjacent coast of Mexico; (2) Senegambia and Ivory Coast of Africa; (3) Brazil. From these homes the disease is frequently introduced into tropical and subtropical parts, epidemics occurring between 33 degrees north and 23 degrees south—that is, from Charlestown to Rio de Janeiro. In 1864 twenty cases of the disease occurred at Swansea, but epidemics in temperate regions are unknown, and, in the light of our present knowledge of the etiology of the disease, not to be expected.

Nature of the Virus and Means of its Transmission.—In 1881 Finlay, of Havana, suggested that the disease was conveyed by mosquitoes, a view which was established by the work of the United States Commission in 1901. It has been proved that

the virus of the disease can pass through a Berkefeld filter, that it is present in the patient's serum during the first three days of the disease, that heating to 55° C. for ten minutes destroys it, and that it is transmitted by the common West Indian mosquito, *Stegomyia calopus*. Twelve days elapse before a stegomyia which has bitten a Yellow Fever patient in the early days of the disease becomes capable of inoculating the disease by its bite. During this period the parasite apparently undergoes a cycle of development in the insect's body. The infected mosquito remains infective throughout life, which in some cases may extend to four and a half months; and, in addition, the virus may be transmitted to a new generation developed from its eggs—a fact which explains the persistence of the disease in certain localities without any new cases being introduced.

Factors influencing the Occurrence of the Disease.—It is essentially a disease of seaports and places of low altitude, and for its prevalence a winter temperature of 20° C. is necessary. The disease is most frequently met with in the insanitary quarters of a city. Fresh arrivals in a country are most liable to be attacked, a few years' residence conferring a certain degree of immunity. The darker-skinned races are less susceptible than the fair-skinned, and even the races of Southern Europe suffer less from the disease than those of the North.

Prevention.—(1) Isolation of the patient, and screening him from mosquitoes. (2) Destruction of the mosquitoes in the house or ship and in the neighbourhood. Sulphurous acid gas is an efficient insecticide. To stamp out the disease in an epidemic area, a vigorous campaign should be conducted against the *Stegomyia calopus*. The breeding-places of the insect—*e.g.*, cisterns, water-barrels, tins, puddles, etc.—should be removed. A staff of sanitary inspectors is necessary to enforce attention in such matters.

The stegomyia, unlike the anopheles, is essentially a town dweller, and hence it is in the towns themselves, and not in the country, that the most rigid precautions should be taken. The disease is not conveyed by fomites, but disinfection of clothing, mattresses, etc., should be practised, lest they might harbour living stegomyia. Mosquitoes cut off from water—

e.g., in trunks, clothing, etc.—probably do not live longer than five days.

Dengue.—This disease has many points in common with Yellow Fever. Thus, (1) it is identical with it in its geographical distribution; (2) the virus is filterable, and is (3) conveyed by a mosquito—the *Culex fatigans;* (4) it affects maritime towns, and rarely spreads inland. The disease has some clinical resemblance to Influenza, and, as with the latter, a considerable percentage of the population are stricken at the same time. The disease is rarely fatal.

Sand-Fly Fever.—This is a fever of a few days' duration, found in Malta, the Mediterranean seaboard, and in India. This virus is filterable, and is conveyed by the sand-fly (*Phlebotomus pappatasii*).

Tick Fever.—This disease occurs in Uganda, the Congo, Central and East Africa, and is due to infection with a spirochæte very similar to, if not identical with, the spirochæte of Obermeier, found in 1873 in the blood of patients suffering from Relapsing Fever. The two diseases are probably identical, Tick Fever being transmitted by ticks (*Ornithodoros moubata*), while Relapsing Fever is probably conveyed by bugs and pediculi.

Relapsing Fever was very prevalent in Ireland during the great famine of 1847, it and Typhus Fever working fearful havoc among the famished peasants.

The preventive measures are obvious. In localities infected with Tick Fever, travellers should avoid old camping-grounds, since the latter may harbour infected ticks.

Sleeping Sickness.—This disease, which is uniformly fatal, and which is very insidious in its onset, is characterized by an enlargement of the cervical glands, spleen, and liver, and extreme debility and lethargy, which finally passes into coma and death. The disease is now recognized as the terminal stage of what is termed Trypanosome Fever, which was shown by Forde and Dutton to be due to infection with the *Trypanosoma gambiense,* found in the blood and in the fluid withdrawn by puncture from the enlarged lymphatic glands. This same micro-organism was discovered by Castellani in the cerebrospinal fluid of Sleeping Sickness patients, the onset of Sleeping

Sickness being due to an invasion of the meninges by the parasite. Trypanosomes are long spindle-shaped protozoa, containing a macro- and a micro-nucleus, and provided with a terminal flagellum and a lateral undulating membrane.

The disease is found along the margins of the rivers and lakes of Central and Western Africa, and has recently been recognized in Rhodesia. The Rhodesian type of the disease is due to infection with a special variety of trypanosome—the *Trypanosoma rhodesiense*—which is conveyed by the *Glossina morsitans*, and not like the usual type, which is transmitted by the *G. palpalis*.

The distribution of the disease is determined by the presence or absence of the insect host. Kleine showed that the fly does not merely mechanically carry the trypanosome, but that it is only after an elapse of twenty days from the time of biting a patient or animal suffering from the disease that the fly is capable of infecting others. The fly then remains infective for the remainder of its life, which may be as long as seventy-five days. Infected flies have been captured on lake shores in Uganda two years after removal of the natives, so that the wild game harbouring the trypanosome probably preserve the infectivity of the flies.

Preventive Measures.—The prevention of the migration of infected natives into unaffected fly areas. This will involve the medical inspection of natives passing from one district to another. At one time it was thought that evacuation of infected areas would very soon abolish the infectivity of the flies in that area; but if, as is probable, there is a reservoir of infection in the wild game, this measure is worse than useless, since the evacuated areas soon relapse back into a condition of jungle.

Kala-Azar, a cachectic condition associated with enlarged spleen and liver, occurring in epidemic form in Assam, and in endemic form in other parts of India and the tropics. In the large endothelial cells of the spleen and liver, small rounded bodies—the Leishman-Donovan body—are found. Occasionally these are also found in the leucocytes of the blood. These are a phase in the development of a flagellated protozoon—a Herpetomonas which is very similar in appearance to a trypanosome, but has no undulating membrane. Cultures of such

flagellated organisms can be obtained by incubating splenic blood withdrawn from a case and received into sodium citrate solution, and incubated at 20° to 25° C. It is as yet undetermined in what form the parasite enters the body—whether as the oval "Leishman-Donovan body," the flagellated cultivation form, or a thin spirilla form; and, though the general opinion seems to be that an insect transmits the disease, there is no agreement as to whether a bed bug, a mosquito, or a flea, is the vector.

Dysentery.—A disease characterized by ulceration of the large intestine, and the presence of blood and mucus in the stools. Two forms of the disease are recognized: one, the tropical form, being due to infection with a protozoon—the *Entamœba histolytica*, the other, which is world-wide in its distribution, due to infection with the bacilli of Shiga and Flexner and their variant forms. The amœbic form is common in Egypt, the United States, and Philippines. The causative organism must be distinguished from the non-pathogenic amœba coli which is present in the intestine in 20 to 50 per cent. of healthy people. The *Entamœba histolytica* burrows its way into the bowel wall, and often contains in its interior red blood corpuscles. In its method of spore-formation it differs from the amœba coli. Often associated with Tropical Dysentery, abscesses occur in the liver, and in the walls of these amœbæ are found. Under certain conditions—*e.g.*, when the stools are allowed to dry—spores ensheathed with a tough membrane are formed, which, if swallowed, can resist the action of the gastric juice, and then infect the large bowel. Schaudinn caused dysentery in cats by feeding them with milk containing the spores of the *Entamœba histolytica.*

The bacillary form is found in every quarter of the globe; it attacks alike explorers in the Arctic regions and in the tropics. It especially prevails in warm climates. In this country outbreaks of dysentery are frequent among the inmates of asylums, but are rare among the general population. The relationship of summer diarrhœa of young children to dysentery is not yet decided, since dysentery bacilli have been found in the stools of such children in America, but not in this country.

Predisposing Causes.—Foremost among these are conditions which lower the vitality of the body, such as fatigue and exposure to alternations of heat and cold; hence the disease is common in armies on active service. The infective agent is swallowed, and water, milk, or vegetables, may be vehicles of infection. The essential cause of the disease is specific pollution of soil and water, and where dysenteric stools are exposed to the air, flies may convey infective matter from them to food.

The preventive measures consist in attention to sanitation, and especially the thorough disinfection and safe disposal of dysenteric stools. Only pure water should be drunk, and salads should be avoided unless the source of the vegetables is above suspicion. Special attention should be paid to these points during the late summer and early autumn, since the disease is most prevalent at that season. It has been shown by Leonard Rogers that it is possible by subcutaneous injections of emetine (the active principle of ipecacuanha) to destroy amœbæ present in the body—a discovery of paramount importance not only in the treatment, but also in the prevention of Tropical Dysentery.

Cholera.—A disease characterized by profuse watery stools, collapse, and in many cases rapidly fatal termination. In the liquid evacuations a spiral- or comma-shaped microorganism is present—the *Spirillum* or *Vibio choleræ,* discovered by Koch in 1883, and now regarded as the cause of the disease. The disease is endemic in the delta of the Ganges, and from this home from time to time it extends east and west in epidemic form. Seven distinct invasions of Europe took place during the nineteenth century, and at the present time the disease is slowly spreading westward—Russia, Turkey, Eastern Prussia, and Italy, having already been attacked. The disease is contracted by swallowing water, milk, or other food, containing the specific vibrio.

When cholera is introduced into a new district, it follows the lines of traffic, and is carried thither by cholera infected rags, cholera-infected food, a cholera-infected man, or by a "cholera carrier." "Cholera carriers" may never have presented any sign of the disease, but simply have been in contact with a case.

Cholera is essentially a water-borne disease, and the installa-

tion of a pure water-supply is a safeguard of the first importance. When water is the source of infection in a town, there is an explosive outbreak, many cases occurring simultaneously.

Such an epidemic was that which occurred in Hamburg in 1892-93, the disease being due to specific pollution of the Elbe water, which was supplied unfiltered to the citizens. In Hamburg, with a population of 640,000, almost 17,000 cases occurred, half of which were fatal; whilst the adjacent town of Altona, supplied with water taken from the Elbe lower down the river, but filtered through sand before distribution, had only 516 cases in a population of 148,600.

The vibrio can survive for long periods—probably months—in sewage-polluted water. The disease is most prevalent in places where the soil is moist, aërated, and polluted, such a soil apparently favouring the saprophytic existence of the vibrio, and facilitating its access to wells. According to Pettenkofer, the sudden depression of the level of the subsoil water, especially after it has stood at a moderately high level, favours the epidemic occurrence of the disease.

Prevention.—(1) In an unaffected district, the isolation of cases that may be introduced, and a strict surveillance of all who have been in contact with them. In this country this means the enforcement of the Cholera Orders issued by the Local Government Board. (2) In an affected district, (*a*) the isolation of the patient, (*b*) disinfection of his excreta and clothing, (*c*) the boiling of all water, and (*d*) the use of preventive inoculation, a system introduced by Haffkine, and consisting of the subcutaneous injection of dead virulent cholera spirilla. The protective effect of such inoculation commences at once, and lasts about fourteen months, after which it rapidly diminishes. It is found that ten times more cases occur among uninoculated than among inoculated, living under the same conditions. If, however, the inoculated contract the disease, their chances of recovery are much the same as those of the uninoculated.

Plague.—A disease due to infection with the *Bacillus pestis*, which is endemic in certain parts of Asia, and which from time to time has overrun Europe. The Great Plague of London, in which about 70,000 persons died, occurred in 1665; and after

that epidemic had run its course, the disease did not reappear on British soil till 1900, when a small outbreak, involving some thirty persons, occurred in Glasgow. Since then a few cases have been reported in various parts of Great Britain—*e.g.*, Leith (1906), Liverpool (1908), Suffolk (1910).

There are three chief forms of the disease—the Bubonic, characterized by the presence of buboes, or enlargement of the lymphatic glands in the groin, axilla, and neck; the Septicæmic, in which the bacilli are present in the blood-stream; and the Pneumonic, in which the lungs bear the brunt of the attack.

Since 1896 the disease has raged in India, and in some years (1907) has been responsible for over 1,000,000 deaths in that country. The disease was first introduced into Bombay from Hong-Kong, where the *Bacillus pestis* had been discovered by Kitasato and Yersin in 1894.

Predisposing Conditions.—Plague is essentially a filth disease, and is almost invariably found associated with insanitation, overcrowding, and uncleanliness.

Method of Spread.—The disease apparently has no relation to water and soil, the bacillus not surviving long in these media. The Pneumonic form is contracted by the inhalation of minute particles of mucus and saliva containing the bacilli, which are sprayed out by the patient into the air in his neighbourhood.

Recent work of the Plague Commission in India, by experimental and epidemiological evidence, has established the view that Bubonic and Septicæmic Plague are conveyed through the agency of infected fleas, which obtain their infection from plague-infected rats. It has been known for long that preceding an epidemic of plague there is a high mortality among rats. There are two chief species of rats in India—the *Mus decumanus*, or brown rat, found in sewers and in the basements of dwellings; and the *Mus rattus*, or black rat, which is a house rat, living in the tiles, thatch, etc.

In an endemic area season has a marked influence on the incidence of the disease, which abates with the advent of dry, hot weather, probably due to the diminution in the number of fleas which occurs at this time. In India the species of flea concerned in the transmission of the disease is the *Pulex cheopis*, in Europe the *Ceratophyllus fasciatus*. It has been

shown that the intestines of fleas caught in infected houses contain living virulent plague bacilli. When the flea bites, it at the same time defæcates, and scratching serves to rub the bacilli into the punctured wound. The bacilli also grow in masses in the flea's œsophagus, and occlude it, and mingle with the blood that the flea sucks and attempts to swallow. Some of this infected blood is then regurgitated back into the puncture.

The prevention of Plague proceeds along three lines—(1) Preventing the transmission of the disease from one place to another; (2) preventing the spread in an infected locality; (3) removal or modification of local conditions favourable to the growth of the disease.

1. The preventive measures against the introduction of Plague into the United Kingdom are contained in Orders issued by the Local Government Board. These provide for—(*a*) The medical inspection of all persons on board ships arriving from infected or suspected ports; (*b*) removal to an isolation hospital of any persons suspected to be suffering from Plague; (*c*) the disinfection of infected articles and of the part of the vessel occupied by the case; (*d*) the taking of names and addresses of all persons, including the crew, on board ships where suspected cases of Plague have occurred. Such persons are allowed to proceed to their destination, and their names and addresses are transmitted to the Sanitary Authorities concerned, so that they may be kept under the observation of a medical officer of health for ten days. To facilitate the diagnosis of the disease, a Sanitary Authority can obtain the assistance of an expert bacteriologist of the Board. Since rats play an important part in the spread of the disease, the destruction of those on board a plague-infected vessel should be aimed at, and care should be taken to prevent any communication between the rats on the shore and those on the vessel, by placing guards on the cables, and raising the gangways at night. The rats may be poisoned by such gases as sulphurous and sulphuric anhydride, and carbon monoxide and carbon dioxide, or by trapping, or by the use of poisoned food. Attempts have been made, in some cases with success, to produce an epizootic among rats by laying food for them containing living Danysz

bacilli. Great care should be exercised where this virus is used, lest human food may get contaminated with it; for, although in the majority of instances it seems to be innocuous to man, still it belongs to the class of food-poisoning bacteria, and several outbreaks of food-poisoning have been attributed to the use of this virus.

Dead rats should not be handled, but should be at once cremated, or at any rate dipped in crude carbolic acid.

2. In an endemic district the measures to be taken to prevent the spread of Plague are much the same as those taken in the case of infectious diseases generally. These will include —(*a*) The notification of every case, the diagnosis being assisted by an expert bacteriologist; (*b*) the isolation of the patient; (*c*) the disinfection of the house and clothing; (*d*) the keeping of all who have been in contact with the patient under observation; (*e*) house-to-house visitation for the discovery of cases in the neighbourhood; (*f*) the prompt and safe disposal of the bodies of persons who have died from the disease; (*g*) the destruction of rats; (*h*) the abatement of all insanitary conditions in the locality. The making of houses rat-proof is most effective, but is impossible to accomplish in the tropics. (*i*) The use of plague vaccines, consisting of broth cultures of plague bacilli, sterilized by heating to 65° C.—Haffkine's plague prophylactic. Statistics definitely prove the value of this measure. Professor Simpson, in the Croonian Lecture of 1907, stated, in reference to the use of this preventive treatment: " The average reduction amounts to three times fewer attacks among the inoculated, and should the inoculated take Plague, the chances of death are reduced at least twice. Accordingly, the chances of escape from death are 6 to 1 in favour of the inoculated compared to the uninoculated. In many cases they are at least 10 to 1— that is, out of 1,000,000 deaths among a non-inoculated population, if that population had been inoculated and exposed to the same infection, 900,000 lives would have been saved."

Leprosy.—This disease is to-day prevalent in the East, just as it was in Biblical times. It is due to infection with an acid-fast bacillus, which in many respects resembles the tubercle bacillus, and which was discovered by Hansen in 1873. The bacilli are present in enormous masses in the affected tissues,

and as a result of their presence, nodular swellings are formed, sometimes in the skin, sometimes in the sheaths of nerves. Ulceration and trophic disturbances follow, leading to deformities and loss of function, but as a rule the disease is only fatal after many years.

From the beginning of the Christian era onwards the disease was introduced into Europe, and was common in the Middle Ages, the Crusaders probably assisting in its dissemination. At the present time the disease lingers in Norway and Iceland, Turkey, and a few other parts of Europe. The last reported indigenous case in Great Britain was seen in the Shetland Islands in 1798. As we have already mentioned, the disease is common in the East—*e.g.*, in India and China—and in Cape Colony there is a considerable number of cases; while in the Sandwich Islands a considerable proportion of the population are affected.

Predisposing Causes.—The disease is commoner among the poor than among the well-to-do, and is often associated with insanitary conditions. Whether the disease is in any way influenced by diet is uncertain; some authorities consider that a diet into which fish largely enters predisposes to the disease, and in support of this theory point to the fact that the disease is commoner on the sea-coast than in inland regions. On the other hand, cases of leprosy occur among communities who seldom or never eat fish.

Mode of Infection.—The onset of the disease is exceedingly insidious, the incubation period being in some cases of several years' duration. Apparently, close and continued contact with lepers is necessary to contract the disease. A fatal case was reported by Dr. Hawtry Benson (1877), of Dublin, in which a lad of that city appeared to have developed the disease from sleeping in the same bed and wearing the clothes of his brother, who as a soldier in India had become infected. The finding of acid-fast bacteria in the bodies of bugs, flies, and mosquitoes, caught in leper houses, lends some support to the view that the disease may be conveyed by insects.

Preventive Measures.—These include notification of the disease, and as far as possible the isolation of the leper. The latter measure was extensively adopted in the ancient and

medieval world, and the establishment of leper asylums in Norway in the middle of the last century seems to have contributed to the decline of the disease in that country. Compulsory isolation in special institutions would be an effective measure, but on account of the expense and suffering entailed —banishment from home and family—is impracticable.

The discharges from the leprous ulcers contain the bacilli, and should be disinfected. A leper should be provided with a separate bed, clothes, eating utensils, etc.

Malta Fever.—This is a disease characterized by symptoms resembling to some extent those of a prolonged attack of Typhoid Fever and Rheumatic Fever. It is prevalent in all parts of the shores of the Mediterranean and Red Seas, and in recent years has been recognized in Southern and Central Africa, India, Brazil, and Texas. The *Micrococcus melitensis*, discovered by Bruce in 1887, is the infecting parasite, and is found in the blood and spleen, and is excreted in the urine in 50 per cent. of the cases. The blood-serum exerts a specific agglutinating action on an emulsion of the bacterial growth, and by this test, as well as by blood-cultural methods, a diagnosis can be made.

The *M. melitensis* is an exceedingly minute micro-organism, and can survive for eighty days on infected clothing. It is very resistant to desiccation, so that dust may play some part in its dissemination. The work of a British Commission (1905-1907) has definitely established the fact that the consumption of goat's milk containing this germ is the main means by which this disease is contracted. It was found that 50 per cent. of the goats in Malta were infected with the micrococcus, and that in 10 per cent. the germ was excreted in their milk. The infected goats appeared to be in quite good health, and their milk presented nothing unusual in appearance and taste. The history of the s.s. *Joshua Nicholson* amounts to an experiment on human beings, conducted under conditions in which all sources of infection were eliminated except that of goat's milk. In 1905 this steamer shipped sixty-five goats at Malta for America, and during the voyage the crew partook of their milk. As a result, a considerable proportion of the men developed Malta Fever, and it was subsequently shown that

the herd was infected, the micrococcus being isolated from the milk of several of the goats.

Until the year 1906 Malta Fever was responsible for much sickness amongst our soldiers and sailors in Malta, the average yearly incidence being 37 per 1,000 in the case of soldiers, and 28 in the case of the sailors. With the prohibition of the use of goat's milk, the disease has become extinct in the garrison, whilst the civil population still suffers severely. In 1909 municipal authorities in Malta obtained power to destroy infected goats. In the course of two years 461 milch goats were slaughtered, and during this period the human incidence of the disease declined by one-half.

Other preventive measures are isolation of the sick, and disinfection of excreta, fomites, etc.

In the chapter on Food, two other tropical diseases, Beri-Beri and Pellagra, are described. In addition to the foregoing, Typhus Fever, Typhoid Fever, Smallpox, Pneumonia, and Tuberculosis, are as prevalent in the tropical as in the temperate zones.

CHAPTER XVII

DISINFECTION

The infective agent being readily transmitted from a patient suffering from a communicable disease to his surroundings, it is necessary to endeavour to kill it as soon as it leaves the patient's body, and also to disinfect the various articles in the room that may have been in contact with it. It is most important to disinfect during the progress of the disease all secretions and excretions of the patient, and in the case of diseases that are transmissible by insects, to destroy these vectors of infection. The public has great faith in the disinfection of the room occupied by the patient at the close of the occupancy by him, but it has yet to be impressed with the absolute necessity for precautions during the illness. In the case of certain diseases—*e.g.*, Influenza, Whooping-Cough, Cerebro-Spinal Fever—the causative micro-organisms are so delicate that they rapidly die when ejected into the outer world, and hence disinfection of the room at the end of the illness is almost uncalled for; but, on the other hand, the disinfection of the patient's throat and mouth needs constant attention. In other diseases, more particularly those attributable to filterable viruses, the virus can survive for long periods in infected clothes, etc., and in such cases most thorough disinfection of fomites and of the room is required. Examples of such diseases are Scarlet Fever, Measles, Smallpox, and Poliomyelitis. Many of the gaseous disinfectants employed for room disinfection also act as insecticides, and their irritating effect on the nasal mucous membrane necessitates the thorough aëration of the room before it can be again occupied—not unimportant considerations in dwellings where the cult of cleanliness and fresh air is not practised.

In dealing with the different communicable diseases, we have mentioned the secretions that are infective, and the usual

methods of disinfection employed. Secretions of nose, mouth, and air passages should be received on pieces of muslin rag, which can at once be burnt. In the disinfection of the stools and urine, liquid disinfectants are employed in adequate strength, and after being exposed to their action for an hour, the excreta are passed down the drain, or in a country district are buried in a place remote from a water-supply.

If the patient is nursed at home, a room near the top of the house should be selected, and from it all unnecessary furniture, carpets, and curtains should be removed. The room should have an open fire, which is useful not only for the purposes of heating and ventilation, but also for cremating discharges from the patient's nose and throat. The nurse in charge of the patient should sleep in an adjoining room, where she should also take her meals apart from the other inmates. Dishes used by the patient should be kept separate from those of the rest of the household. There should be little or no communication between the members of the family and the sick-room. A sheet steeped in a disinfectant is drawn over the door, with the object of intercepting bacteria and of warning off intruders.

Forms of Disinfectants.—The terms "disinfectant" and "germicide" are synonymous. Disinfectants are "substances which can prevent infectious diseases from spreading by destroying their specific poisons" (Parkes). An antiseptic, strictly speaking, is a substance that prevents the activity of the bacteria responsible for putrefaction and suppuration, but is often used as synonymous with a germicide. Disinfectants when diluted beyond a certain strength act only as antiseptics, and not as germicides.

Deodorants destroy or mask effluvia. Many of these have an oxidizing or reducing action, resulting in the breaking up of organic bodies and sulphuretted hydrogen; and if present in sufficient amount, they have a germicidal action as well. Examples of deodorants are chlorine, permanganate of potash, sulphate of iron, carbolic acid. Blocks of silica or peat impregnated with carbolic acid are often used in public urinals, and tend to prevent decomposition and the generation of offensive gases, and at the same time their presence tends to sweeten the air.

In Nature, infective material is destroyed by exposure to light, especially sunlight, and to the action of desiccation. It is the blue and violet rays in light that produce the germicidal effect. It has been shown by Semple and Greig that white drill cloth soaked with urine containing millions of typhoid bacilli was rendered sterile after two hours' exposure to the Indian sun. In the chapter on Water we have already referred to the disinfecting action of the rays emitted from the mercury-vapour lamp.

Of physical disinfecting agencies, heat is the most effective, and is especially useful for the disinfection of clothing. Dry heat is extensively used in laboratories for the sterilization of glassware, and in Public Health work for the disinfection of leather objects and books, which would be injured by steam. Books, when being disinfected, should be placed on their ends on a wire network, and should be opened out so that the hot air can pass between the leaves. An effective method of disinfecting books is to expose them in a vacuum at a temperature of 60° C. to the vapour of formalin.

Moist heat is employed for the disinfection of clothing, and as it possesses great powers of penetration, even the interior of mattresses can be disinfected. Steam may be saturated or superheated, the latter quality being acquired when the steam is brought into contact with a surface at a higher temperature than 100° C. without the pressure having been increased. If the pressure under which the steam is generated is increased, the steam can acquire a higher temperature than 100° C., and still remain saturated. For purposes of disinfection, saturated steam is preferable, since its power of penetration is enormous, compared with that of superheated steam or hot air. Saturated steam readily condenses when brought into contact with an object cooler than itself, and since the resulting moisture occupies only a fraction of the volume occupied by the steam, a partial vacuum is created, into which more steam rushes, and in this way the object gets thoroughly permeated with the steam. Superheated steam has more the properties of a gas than those of a vapour, and requires to part with its superheat before acquiring powers of penetration other than those of conduction and convection. Most Sanitary Authorities

now possess the necessary appliances for the disinfection of clothing, etc., coming from infected houses, and carry out the process free of charge.

One form of public disinfector is shown in Fig. 24. A disinfecting station is divided into two halves by a brick wall, into which the disinfecting apparatus is built. On one side of the wall is the room for infected articles; on the other side these articles are taken out of the apparatus after being disinfected. From Fig. 24 the general structure of such a disinfector can be learned. It consists of a large oval cylinder, provided at either end with tight-fitting doors, and into it steam generated in a boiler is admitted. The articles of clothing are suspended from hooks, or lie along the bottom of the wire cage, which passes along rails into the apparatus. Before the steam is admitted the outer hollow jacket is heated with a current of steam, and another current rushing through a vacuum-box at the side of the disinfector aspirates air from the interior of the apparatus and the clothing contained in it, and so facilitates the penetration of the steam into the latter.

Exposure to a temperature of 115° C. for twenty minutes is sufficient. Some disinfectors are provided with a special contrivance which records the temperature reached, and the length of time occupied in the disinfection—a most important means of controlling the efficiency and thoroughness of the work done.

Liquid Disinfectants.—In the hospitals of the kingdom, carbolic acid (C_6H_5OH) and perchloride of mercury ($HgCl_2$), in dilution of 1 in 20 and 1 in 1,000 respectively, have been in use since the introduction of Listerism, and at the present time the tincture of iodine is freely used for the disinfection of the skin and of lacerated wounds. Most salts of the heavy metals —*e.g.*, Hg, Cu, Fe—are in solution of certain concentrations germicidal, and were at one time widely used in the disinfection necessary in dealing with cases of infectious disease; but the fact that they are precipitated from solution by albuminous substances, and so rendered inert, and that many of them are poisonous, are grave disadvantages. Copper sulphate dissolved in water to the extent of 1 part in 1,000,000 is effective in preventing the growth of algæ in drinking-water. Within

PLATE XI.

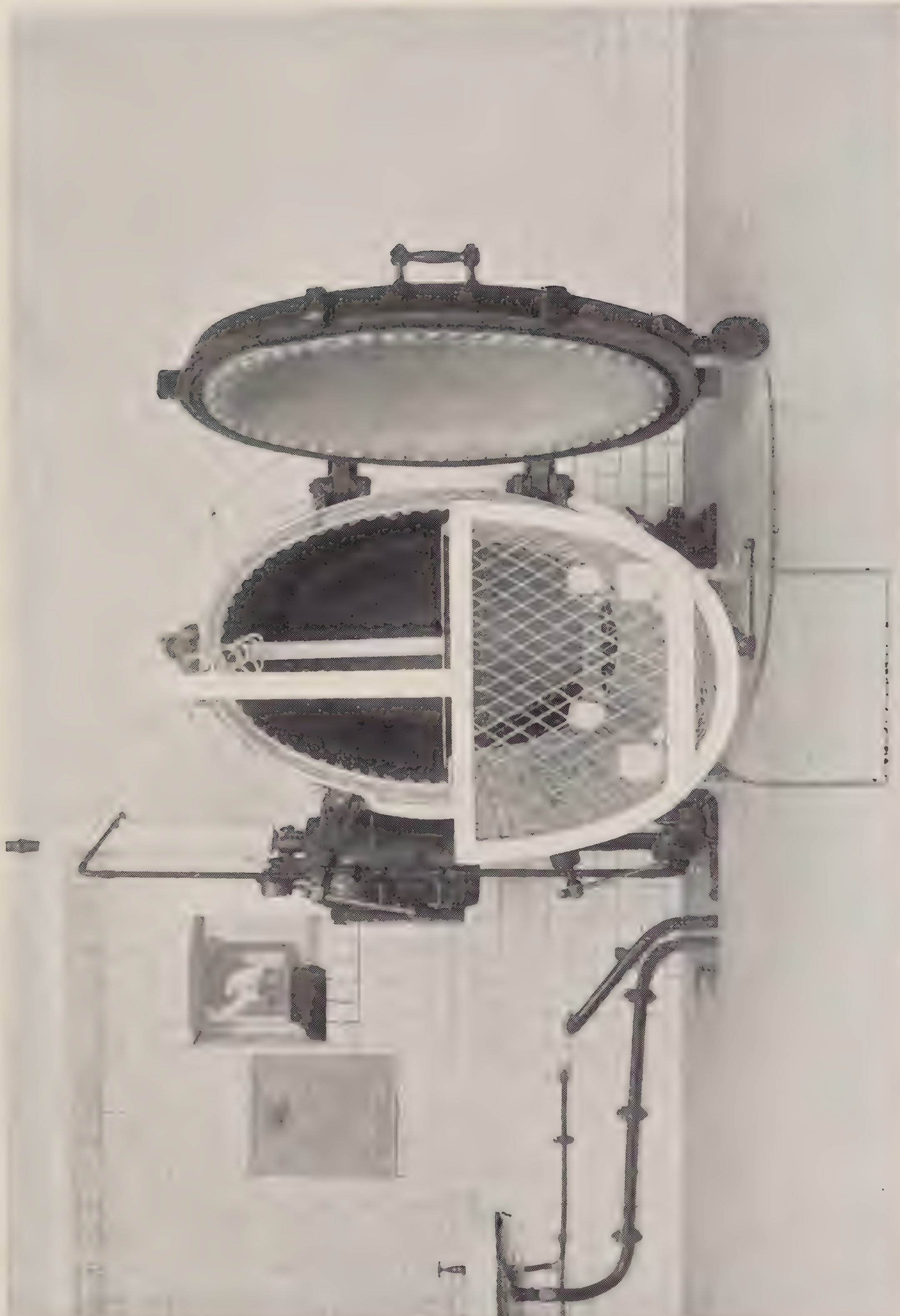

Fig. 24.—End of steam disinfector at Belfast Fever Hospital projecting into room in which infected clothing is received.

recent years non-poisonous derivatives of coal-tar, mainly cresols—$C_6H_4(CH_3)OH$—have come into extensive use, and possess high bactericidal properties. These coal-tar products are insoluble in water, but in their preparation as disinfectants substances that enable them to form a fine emulsion when diluted with water are added to them. These emulsifying agents are usually albumin or soap, and since the latter is largely precipitated when it is mixed with a hard water, the former is preferred. Examples of such disinfectants are cyllin, kerol, cofectant, and in dilutions of 1 in 300 they are suitable for most purposes. An ideal disinfectant should possess the following qualities: (1) It should be a powerful germicide, (2) be non-poisonous to human beings, (3) and its germicidal power should not be markedly reduced by the presence of organic matter; (4) it should possess high powers of penetration, (5) be cheap, and (6) not disagreeable to the sense of smell, and not irritating to mucous membranes; it should (7) be readily diffusible, (8) non-injurious to fabrics, colours, etc., and (9) should be miscible with ordinary tap-water in all proportions to form a stable solution or homogeneous emulsion.

Disinfectants are only efficient when dilution does not proceed beyond a certain working strength, which varies with different agents. As a standard with which to compare other disinfectants, a 1 in 100 solution of carbolic acid has been proposed; and as standard bacteria on which the germicidal power can be exercised, the *Bacilli typhosi* in a twenty-four hours' broth culture. Various dilutions of the disinfectant are made, and by experiment it is determined what is the highest dilution which kills the typhoid bacillus in the same time as the 1 in 100 solution of carbolic acid. This dilution divided by 100 gives the "carbolic acid coefficient," or the Rideal-Walker (the introducers of the method) coefficient, of the disinfectant in question. In a certain case, suppose that a 1 in 800 dilution of the disinfectant was as effective as a 1 in 100 solution of carbolic acid, then the carbolic acid coefficient $=\frac{800}{100}=8$. Many of the coal-tar derivatives have coefficients of 10 to 20. In employing liquid disinfectants, it is

important that the material—*e.g.*, typhoid stools—should be thoroughly mixed with the disinfectant, and that an efficient working strength is present in the total volume. For instance, to disinfect a pint of urine, it would be necessary to add to it a pint of a 1 in 10 solution of carbolic, so that the working strength might be 1 in 20.

Liquid disinfectants are sometimes employed for disinfecting the walls and floors of rooms, being sprayed over these by means of special machines. Solutions of perchloride of mercury (1 in 500), or of formalin (1 in 200), are often used for this purpose. In the case of formalin, the pungent vapours given off render the work trying.

Formalin. This is a solution of formaldehyde (HCOH) in water. It contains 40 per cent. of the gas. If an attempt is made to prepare a more concentrated solution, a portion of the formaldehyde is polymerized, and is deposited as a solid paraform.

Formaldehyde has an irritating effect on the mucous membrane of the eyes, nose, and mouth, but is non-poisonous. In solution it is used as a fixative for animal tissues, and on this account it is unwise to use it for the treatment of linen soiled with blood or other albuminous substance. In 5 per cent., or even in a 1 per cent. solution, it is a most efficient germicide. Both in the gaseous and in the liquid state it possesses great powers of penetration.

Lime.—When limestone ($CaCO_3$) is burnt in a kiln, CaO results. The addition of 1 pint of water to 2 pounds of lime results in the generation of heat and the formation of $Ca(OH)_2$, or slaked lime. Freshly slaked lime should always be prepared, since on keeping it gradually takes up CO_2 from the air with the formation of the inert $CaCO_3$. Milk of lime consists of 1 part of slaked lime and 4 parts of water. Whitewash consists of diluted milk of lime, with size added, to enable it more readily to adhere to surfaces.

Milk of lime is a very effective germicide when it has been freshly prepared, and, being cheap, can be used for disinfecting privies, byres, stables, etc. For disinfection of fæces, a solution containing 1 part of slaked lime and 4 parts of water should be added to an equal volume of the stool.

Chlorinated Lime.—This is prepared by passing chlorine over moist calcium hydroxide. Its chemical composition is very complex, but calcium hypochlorite seems to be the active disinfecting principle contained in it, and a good sample should contain 33 per cent. of available chlorine. A solution of sodium hypochlorite — chloros — containing 20 per cent. available chlorine, is now put on the market.

In watery solution, hypochlorites are most powerful germicides, as we have already seen in the treatment of water and sewage; but in the presence of organic matter they are readily decomposed, so that large quantities must be added. For disinfecting fæces, the dry powder should be added to the extent of 5 per cent. to the watery stool. For the scrubbing of yards, cesspools, privy receptacles, etc., a 3 to 5 per cent. solution should be employed.

In the chapters on Water and Milk we have already referred to the bactericidal effect of nascent oxygen liberated from ozone and hydrogen peroxide.

Soaps.—For the cleansing of surfaces and the mechanical removal of germs, soap is invaluable. A solution of soap has practically no germicidal effect, and the same applies to most of the antiseptic soaps put on the market. The amount of disinfectant present in the soap is small, and when the soap is employed, only a thin layer is dissolved, containing a quite nsufficient amount of active ingredient for the volume of water used.

Gaseous Disinfectants.—Of these, two are in common use—sulphur dioxide (SO_2) and formaldehyde. In a percentage of 2 to 3 per cent., sulphurous acid is a germicide, but the great and only advantage it possesses over formaldehyde is that it is a powerful insecticide, killing vermin of all kinds. It is also a reliable agent for destroying rats and mice; hence it finds an application in the disinfecting of the holds of ships containing plague-infected rats. For this purpose a special apparatus (Clayton) is commonly employed, in which the oxides of S (SO_2 and SO_3) are formed by the combustion of the mineral, and are propelled by a Root-blower through a coiled metal pipe immersed in water, and then, after being cooled, are conducted by a pipe to the hold of the vessel.

In some cases carbon monoxide is employed for destroying rats, but its use is attended with greater danger than that of sulphur dioxide; it is, however, less injurious to certain kinds of cargo.

In the following columns the relative advantages and disadvantages of sulphur dioxide and formaldehyde are shown:

Sulphur Dioxide.	Formaldehyde.
1. On account of its high density does not diffuse readily.	1. Being of same density as air diffuses readily.
2. Injurious to textile fabrics, colour, and metals.	2. Even paintings not affected by its use.
3. A feeble germicide, a powerful insecticide.	3. A powerful germicide, and useless as an insecticide.
4 Easily procurable, cheap, and readily generated.	4. More expensive, and not so easily evolved.
5. Effective only in a moist atmosphere.	5. Air of room should contain 70 per cent. humidity, and have a temperature of 70°.

Sulphurous acid gas is generated by burning sulphur in an iron vessel or pot partially immersed in water. The sulphur is sprinkled with alcohol to facilitate ignition. The heat of combustion serves to evaporate water and so render the air moist. Since SO_2 is a heavy gas, it should be generated high up near the ceiling. One pound of sulphur would produce on combustion in 1,000 cubic feet of space 1 per cent. of SO_2, but since combustion is usually incomplete, and since it is impossible to make the room air-tight, it is necessary to allow at least 3 pounds of sulphur for every 1,000 cubic feet.

Sulphur dioxide can also be conveniently obtained by burning sulphur candles or by exposing the liquefied gas to the air. Cylinders containing 20 ounces of liquefied SO_2 are on the market, and the gas contained in them passes into the air when the pressure is reduced by cutting the lead pipe which is soldered to their ends. At least two cylinders are required for every 1,000 cubic feet.

Formaldehyde.—If formalin is heated under atmospheric pressure, a considerable amount of the formaldehyde undergoes polymerization. The gas can be vapourized (1) by heating formalin containing 20 per cent. calcium chloride in an autoclave; (2) by heating paraform tablets over a special form of

spirit-lamp, twenty-five 1 gramme tablets for every 1,000 cubic feet; (3) by exposing formalin to a high temperature in a special generator (Novy-Waite and Trenner-Lee); (4) by utilizing the heat produced by the chemical reaction which occurs between a fraction of the formalin (usually one-fifth) and some other substance to vapourize the rest of the formalin. Crystals of permanganate of potash were first used for this purpose. Ten ounces of formalin poured over 5 ounces of potash permanganate crystals contained in a bucket are sufficient for a room-space of 1,000 cubic feet. Instead of potassium permanganate, aluminium sulphate and unslaked lime can be employed. The introduction of these methods has put in the hands of the medical officer of health a most simple and effective procedure for the disinfection of infected surfaces.

Action of Disinfectants.—A chemical union in most cases seems to occur between the disinfectant and the protein of the bacterium. In many cases the protein undergoes coagulation. The action of metallic salts, especially compounds of mercury, has been extensively studied, and it seems definitely established that the disinfecting effects are due in large part to the specific action of the metallic ion, but also in some degree to the anion and to the undissociated part of the salt. The higher the grade of dissociation, the greater is the disinfecting power of the solution. In the undissociated condition in which it exists in solution in absolute alcohol, mercuric chloride has practically no disinfecting power, but this becomes evident with the dissociation which follows the addition of water to the mixture.

The velocity of disinfection increases with the rise in temperature, the process resembling a chemical reaction. Where possible, disinfectants should be used in a warm state, as their effectiveness is enormously increased by even moderate degrees of heat.

Disinfection of Special Objects.

Sputum.—The spittoon, or cup, receiving the expectoration should contain for each volume of sputum an equal volume of 10 per cent. formalin or 5 per cent. carbolic acid.

In hospitals and other institutions the sputum is boiled in a special apparatus before being passed down the drain.

Fæces.—In the bed-pan there should always be a small volume of such disinfectants as a 10 per cent. solution of formalin, 5 per cent. solution of carbolic acid, or a 1 per cent. solution of cresol. The stool is received in the pan and an equal volume of the disinfectant is added, and to facilitate penetration all lumps of fæcal matter are broken up by means of of a stick. The disinfectant should be allowed to act for one hour before the stools are finally disposed of by being passed down a closet or being placed in a privy receptacle. Where the conservancy system is practised, disinfection of the stool by means of an equal volume of milk of lime or of a 5 per cent. solution of chlorinated lime is a suitable procedure. If passed down a water-closet, the residual lime would be liable to obstruct the drain.

Bed and Body Linen.—Since formalin and perchloride of mercury fix blood or fæcal stains in the fabric, the linen should be disinfected in a 1 per cent. solution of a cresol or 5 per cent. carbolic acid, and from this solution should be transferred to a pot containing boiling water and soap.

Rooms.—If it has been found possible to prepare the room in the way described at the beginning of the chapter, the final disinfection at the end of the illness is less difficult. Where rigid disinfection has been practised throughout the nursing of the patient, the necessity for disinfecting of the surfaces of the room and the objects contained in it is not very urgent. The room should be in the same condition as it was during the period of its occupation by the patient, but presses and drawers should be opened. The room should be made as air-tight as possible by plugging up the chimney flue and by pasting paper over the slits in the windows and doors. A gaseous disinfectant, preferably formaldehyde, except in insect-borne diseases—*e.g.*, Plague, Yellow Fever, etc., where sulphur dioxide is superior—is admitted into or generated in the room, which is sealed up for several hours. At the end of the process the doors and windows are thrown open and the room well aired. The linen is dealt with in the manner mentioned above, mattresses, pillows, carpets, and rugs are placed in canvas bags which are damp with a disinfectant and conveyed to the public disinfector. The paper is removed from the walls, the floor and other surfaces washed with soap and water, and the furniture polished.

The Patient as a Source of Infection.—If the patient at the time of his convalescence still harbours the germs of his disease, no amount of disinfection of the room occupied by him will prevent him being a source of danger to his fellows. Instructions should be given to such " carriers " to be most particular in the practice of personal hygiene, and to avoid as far as possible the handling of food which is to be partaken of by others.

Unfortunately, up to the present no certain method has been discovered of destroying the pathogenic bacteria which lead a more or less saprophytic existence in the alimentary and urinary tract of these individuals.

When dead, the patient may be a source of infection, and to mitigate this risk it is advisable to wrap the body in the coffin in a sheet which has been steeped in a 1 in 500 solution of perchloride of mercury. At this point we may conveniently consider the hygienic questions concerned with the disposal of the dead.

DISPOSAL OF THE DEAD.

When the increase of population and its dense aggregation in towns and cities is considered and the fact that at least 14 out of every 1,000 die each year, it is obvious that the disposal of the dead in such a way as not to injure the living is a public health question of considerable importance. It has been estimated that in England and Wales 1,500 persons die daily. There are two sanitary methods of disposal in use—(1) Burial in earth, (2) cremation. The eventual result in both cases is the same—the resolution of the body into simple salts and gases. In the case of **burial** this result is affected by the bacteria contained in the soil. These bacteria are present in greatest numbers near the surface, so that the less deeply a body is interred the more rapid is the resolution. It has been shown by experiment that when bodies are buried at a depth of 1 foot the soft parts completely disappear in one year. The requirements of the Local Government Board, however, are that in the case of a child under twelve years of age the distance from the lid of the coffin to the surface of the ground must be at least 3 feet, and in the case of persons above this age at least

4 feet. No doubt the object of this regulation is to prevent the violation of the dead by animals.

The soil of a burial ground should afford a suitable environment for the bacteria concerned in the resolution of the corpse. A moist, aërated, loamy soil complies with this requirement, and it also absorbs the gases and other products of decomposition, whereas clay is unsuitable owing to its usually impervious character retaining these products, or in times of drought allowing them to escape unpurified through fissures in its substance, with the danger of pollution of water-supplies. The level of the subsoil water should be at least 8 feet from the surface.

Burial in the earth when no overcrowding of the cemetery is permitted is fraught with no danger to the community, even in the case of bodies containing virulent pathogenic bacteria, since these probably do not survive more than one month in the buried body. No nuisance is created by the gaseous products of decomposition, and, in fact, a well-managed cemetery serves as a park or open space.

It is becoming increasingly difficult to obtain suitable ground convenient to large towns at a moderate cost. It has been found that one acre is sufficient for a population of 1,000 for fourteen years.

Cremation is the most sanitary method of disposing of the dead as of other organic matter, and one which has commended itself to men of artistic temperament ; but, unfortunately, popular feeling and religious sentiment in this country are rather hostile to its practice. The friends and relatives of the deceased seem to feel that cremation at a single stroke separates them utterly from their beloved dead; whilst burial allows them to visit the grave and in their thoughts to recall memories of the one who sleeps beneath the sod. The horrors of corruption are not contemplated; to the mourner the body of their friend retains the appearance it presented on the day of burial. The advocates of cremation think with disgust of the slow process of decomposition in contrast to the rapid and purifying action of fire. For nearly a generation facilities for cremation have existed in England, and in the year 1911 there were cremated in the thirteen crematoria, established in the leading cities of the

kingdom, 1,023 bodies, the largest number recorded in any year. In Germany and other parts of the Continent cremation is coming into popular favour more rapidly than in Great Britain. At the present time cremation is more expensive than burial, but when crematoria are more numerous and more frequently used, their cost to the community and to the individual will probably be less than that of cemeteries. The most valid argument against cremation is that exhumation would be impossible, and in consequence homicide would in certain cases go unpunished. In few cases, however, is exhumation resorted to, and whether the thought of it acts as a deterrent to crime is at least doubtful. It is possible that the strict regulation which must be complied with before cremation can be carried out, requiring as they do certificates of the cause of death from two medical practitioners, would bring to light crime which at present the practice of burial allows to go undetected.

In crematoria the powerful heat of the furnace in a few hours reduces the coffin and the body contained in it to ashes. The ashes from the body of an adult amount to 4 pounds; they are removed in an urn which can be placed in a niche in the wall of the building, or buried in the ground. The practice of cremation would permit of the burial of the ashes of the dead within the walls of abbeys and churches without any principle of hygiene being violated, whereas the interment in a church of an uncremated body is hardly in keeping with modern ideas of sanitation.

CHAPTER XVIII

PREVENTION OF INFECTIOUS DISEASES

An awakened public conscience as to the importance of national and personal hygiene is the first essential in the warfare against disease. Such general measures as provide for purity of air, water, food, and soil, and for the sanitary condition of habitation, school, and work-place are most important safeguards against infection.

In the middle of the nineteenth century, when the development of steamboats brought countries into closer association, it became clear that in order to prevent the dissemination of exotic diseases the great nations ought to take concerted action. The result was the holding of the first International Sanitary Conference at Paris in 1851 and subsequent conferences held every few years.

The chief result of these conferences has been (1) the adoption of certain measures against Plague, Cholera, and Yellow Fever; (2) the establishment in 1908 at Paris of L'Office International d'Hygiène Publique, which by means of a monthly publication keeps the various Governments informed of knowledge acquired with regard to infectious diseases, notably Plague, Cholera, and Yellow Fever; (3) the sanitary surveillance of the Red Sea and Persian Gulf necessitated by the journeying of pilgrims to Mecca and the danger of the spread of Cholera thereby.

The international prophylactic measures include—(1) Notification of the other Governments by the Government of the country in which a case of Plague, Cholera, or Yellow Fever appears. The bills of health of a ship leaving an infected port contain information with regard to the presence of these diseases in the port of departure; (2) the prevention of persons presenting symptoms of Plague, Cholera, and Yellow Fever embarking on board ship; (3) regulations with regard to the prevention of the

introduction of Plague, Cholera, and Yellow Fever from ships into a country. Authorized by the Public Health Acts, the Local Government Board has issued special regulations with regard to the introduction of these exotic diseases. An "infected ship" is one on which there is actually on board at the time a case of Cholera, Yellow Fever, or Plague, or on which there has been a case of Cholera or Plague within seven days or of Yellow Fever within eighteen days before arrival. If there has been a case on board during the voyage but not within the periods prescribed above, then the ship is merely "suspected." The master of an "infected" or "suspected" ship must, when the ship is within three miles of land, keep hoisted at the mast-head during the day a large yellow and black flag and during the night a signal of three lights in triangular form. On arrival in port every vessel from a foreign country is boarded by a Customs officer, who ascertains if the ship is "infected" or "suspected." If such is the case he orders the master to moor the ship in a certain position and to allow no one to land during the period of detention. The Customs officer then notifies the Sanitary Authority, and the medical officer of health visits the ship and examines every person on board. Patients suffering from the disease in question are removed, if possible, to an isolation hospital, and suspected cases are kept under observation for two days. The other persons on board are allowed to land and their names and addresses are forwarded to the Sanitary Authority of their place of destination, so that they can be kept under observation. Measures indicated in the regulations are then taken to free the ship from infection. These will include disinfection, destruction of rats, mosquitoes, etc., and in the case of Cholera the provision of a fresh supply of drinking and bilge water. It is obvious from the above that quarantine, which usually implies detention of the infected ship and of people who are well in addition to the sick, is not enforced in this country, and that in consequence the interference with commerce is reduced to a minimum. The results obtained are as good as, if not better than, those recorded in countries practising rigid quarantine. In the chapter on Communicable Diseases the prophylactic measures which would be taken by the householder on the advice of his medical attendant are referred

to. The medical officer of health in virtue of fuller information and of authority given by his position can deal more radically with the prevention of infectious disease. The Infectious Diseases (Notification) Act, 1889, compelled certain diseases scheduled in the Act to be notified to the Sanitary Authority by the medical attendant in a district adopting the Act. By an extension Act, passed in 1899, compulsory notification of the scheduled diseases was instituted throughout England and Wales, and a Sanitary Authority was enabled, with the sanction of the Local Government Board, to add other diseases to the list, which included Smallpox, Cholera, Diphtheria, Membranous Croup, Erysipelas, Scarlet Fever, Typhus, Enteric Fever, Relapsing Fever, Continued Fever, Puerperal Fever. In England now Ophthalmia Neonatorum is compulsorily notifiable. Unfortunately, in Ireland the Infectious Diseases (Notification) Act is still adoptive—*i.e.*, discretion to make use of the powers granted by the Act remains in the hands of the Urban and District Councils. Forms of certificate are supplied to every practitioner practising in the district, and the fee of 2s. 6d. is paid to him for every notification of cases occurring in his private practice. The penalty for default is a fine not exceeding 40s. Reference to the notification of Tuberculosis has been made in the consideration of that disease. On receipt of a notification the medical officer of health or his subordinate visits the house and makes full inquiries and adopts the necessary precautionary measures in conjunction with the medical attendant. The answers to the inquiries are entered up in registers, a separate register being kept for each disease. The main object of these registers is to trace the source of infection by ascertaining if there is any grouping of the cases around any particular water or milk supply, school or work-place. The isolation of the patient should immediately follow the recognition and notification of an infectious disease. In the houses of the working classes, especially where there are children, isolation cannot be provided at home. It is therefore necessary to urge the friends to permit of the patient's removal to a fever hospital provided by the Sanitary Authority. Under certain circumstances the patient's removal can be enforced even against the desire of himself or friends. Where a hospital is provided within con-

venient distance a Justice may, on the certificate of a medical practitioner, order the removal of any person who is suffering from any dangerous infectious disorder, and is without proper lodging or accommodation, or lodged in a room occupied by more than one family, or is on board any ship or vessel. The Sanitary Authority may make regulations for removing to any available hospital and for keeping there as long as necessary any persons brought within their district by vessel who are infected with a dangerous infectious disorder. These powers are given by the Public Health Act, 1875, other important sections of which provide for the disinfection of premises, the conveyance of patients to hospital, and the disinfection of bedding, clothing, etc. It is also enacted in the same Act that it is unlawful for any person suffering from an infectious disease to expose himself wilfully, without proper precautions against spreading the disorder in any street, public place, shop, inn, or public conveyance, or to enter any public conveyance without previously notifying to the owner, conductor, or driver thereof that he is so suffering; or being in charge of any person so suffering to expose such sufferer, or to give, lend, sell, transmit, or expose without previous disinfection any bedding, clothing, rags, or other things which had been exposed to infection from any such disorder; but this does not apply to the transmisssion with proper precautions of articles for the purpose of having them disinfected. The owner or driver of a public conveyance so used is required, under penalty, to have the same immediately disinfected, but he need not convey any person so suffering until he has been paid a sum sufficient to cover any loss or expense incurred by him. Any person who knowingly lets for hire any house or room in which any person has suffered from such disorder without having it and the contents disinfected to the satisfaction of a medical practitioner, as testified by a certificate signed by him, is liable to a penalty not exceeding £20. Any person letting or offering for hire any house or part of a house, who on being questioned as to the fact of there being, or within six weeks previously having been therein, any person suffering from any dangerous infectious disorder, knowingly makes a false answer to such questions, becomes liable to penalty or imprisonment. These provisions have been supplemented by

the Infectious Diseases Prevention Act, 1890, which enacts that any person who shall cease to occupy any house or room in which any person has within six weeks been suffering from any infectious disease (1) must have such house or room (and all articles therein liable to retain infection) disinfected to the satisfaction of a registered medical practitioner as testified by a certificate signed by him; (2) must give the owner notice of the previous existence of such disease; and (3) must not knowingly make a false answer when questioned by the owner or by any person negotiating for the hire of the house or room, as to their having, within six weeks previously, been therein any person suffering from any infectious disease. Penalties of £10 are provided in each case. The Sanitary Authority is required to give notice of these provisions to the occupier of any house in which they are aware there is a person suffering from an infectious disease. Other important sections of the Infectious Diseases Prevention Act, 1890, deal with milk-supplies, disinfection, prompt interment, detention in hospital, and infectious rubbish.

A patient in an infectious disease hospital who upon leaving could not be properly isolated, can be, by order of a Justice, detained in hospital. Infectious rubbish must not be thrown into any receptacle without previous disinfection. The body of a person who has died of any infectious disease must not, without a certificate from the medical officer of health or a registered medical practitioner, be retained for more than forty-eight hours elsewhere than in a mortuary or in a room not used at the time as a dwelling-place, sleeping-place, or work-room.

Where the medical officer of health or any registered medical practitioner certifies that the cleansing and disinfection of any house or part thereof and of any articles therein would tend to prevent infection, the Sanitary Authority may, after twenty-four hours' notice to the owner or occupier, proceed to carry out such disinfection or cleansing unless within that time he informs the Sanitary Authority that he will, within a period fixed in the notice, himself carry out the work to the satisfaction of the medical officer of health. If he fail to do this within the specified period, it is to be done by the officers of the Sanitary

Authority under the superintendence of the medical officer of health, and the expenses may be recovered. Power of entry between 10 a.m. and 6 p.m. is given for the purposes of this section.

If the medical officer of health has reason to believe that the consumption of milk from any dairy (within or without his district) has caused, or is likely to cause, infectious disease to any person residing in the district, he may (if authorized by a Justice having jurisdiction in the place where the dairy is situate) inspect the dairy. He may further, if accompanied by a veterinary surgeon, inspect the animals therein. If after inspection he is of opinion that infectious disease is caused by the consumption of the milk, he must report to the Sanitary Authority, forwarding also any report furnished to him by the veterinary surgeon. The Sanitary Authority may then give not less than twenty-four hours' notice to the dairyman to appear before them and show cause why the supply of the milk in their district should not be prohibited. If in their opinion he fails to show such cause, they may order accordingly, and must give notice of the facts to the Sanitary Authority and the County Council of the district in which the dairy is situate, and to the Local Government Board. The order must be forthwith withdrawn on the Sanitary Authority or the medical officer of health being satisfied that the milk-supply has been changed or that the cause of infection has been removed.

The Public Health Act Amendment Act, 1907, is, like the Infectious Diseases Prevention Act, 1890, an adoptive Act, and gives further powers to the Sanitary Authority to deal with infectious diseases—*e.g.*, (1) if any person knows that he is suffering from an infectious disease he shall not carry on any trade or occupation unless he can do so without risk of spreading the infectious disease; (2) every dairyman shall notify to the Sanitary Authority the occurrence of all cases of infectious disease among his employees; (3) infected clothes may not be sent unless disinfected to a public laundry; (4) children suffering from infectious disease may not attend school; (5) persons suffering from infectious diseases shall not use any book from a public or circulating library, and shall not enter any public vehicle.

Isolation Hospitals.—In the fight against infectious diseases an indispensable weapon in the armamentarium of a community is a well-equipped isolation hospital. It may be stated, as a rule to which there are few exceptions, that it is impossible to provide adequate isolation of cases of infectious disease in the houses of the working classes. Even in the home of the well-to-do it is a great convenience, especially where there are several children, to have the patient isolated in hospital so that its inmates may after the case has been removed and the premises disinfected proceed with their usual avocations. In families engaged in the milk trade or in the handling of food or in the making of clothes, the removal of the case and the carrying out of adequate preventive measures shortens the period during which these industries are stopped, or may even render the arrest of the trades unnecessary.

The diseases for which hospital accommodation should be provided are Smallpox, Scarlet Fever, Diphtheria, Enteric Fever, Cerebro-Spinal Fever, Infantile Paralysis, and Typhus Fever. The three last mentioned are of rare occurrence, but there should be accommodation for them in a fever hospital when an outbreak occurs. When a hospital is properly constructed, its wards can be disinfected in such a way that the same ward may be used at different times for the rarer infectious diseases. In the routine work of a fever hospital there are separate wards for Scarlet Fever, Diphtheria, Enteric Fever, and Smallpox, the latter being in a separate building, as far removed from the others as possible.

Few Sanitary Authorities attempt to provide hospital isolation for cases of Measles and Whooping-Cough. The number of beds which should be provided will vary in different districts, but it may be taken as a rule that one for each thousand of population is a fair provision. The treatment in hospital should be free to all, as the isolation is undertaken in the interests not only of the individual, but also of the community. The middle classes as well as the poor should obtain some benefit from institutions for the erection and maintenance of which, as ratepayers, they are mainly responsible.

Fever hospitals should be permanent buildings, since tem-

PLATE XII.

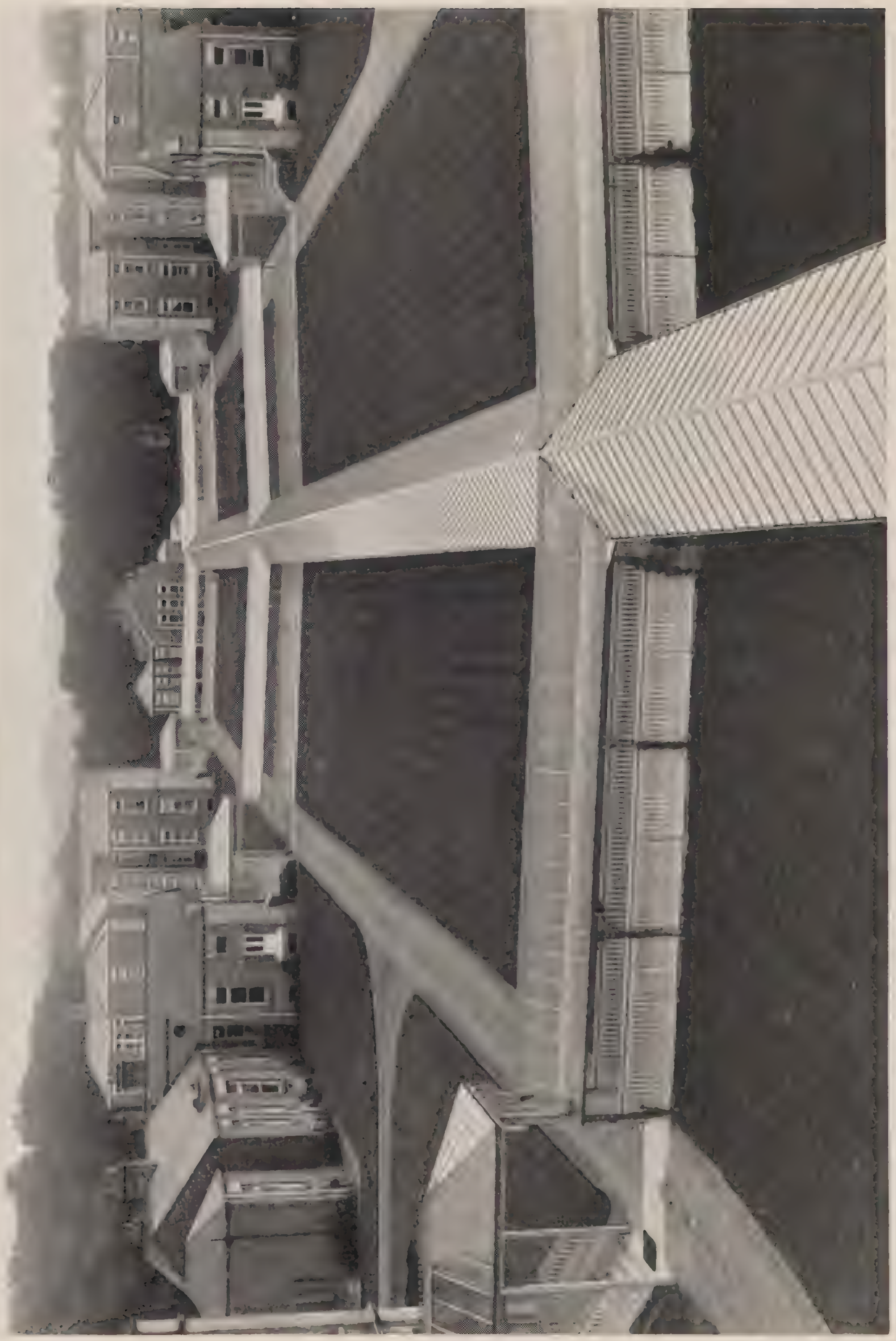

FIG. 25.—View of Pavilions and Glass-Roofed Corridors of Belfast Fever Hospital, seen from Administrative Block.

porary structures made of wood, canvas, or galvanized iron, are rarely satisfactory.

The site of an isolation hospital should be in a thinly populated district outside the town, but easy of access. In their construction, heating, and ventilation, the systems employed for public buildings in general apply. It is not desirable to accommodate more than twenty persons per acre, so that there should be a considerable amount of the site uncovered by buildings. The hospital buildings should be 40 feet from the boundary fence, and where the pavilion system is adopted, the distance between the separate blocks should also be 40 feet.

A large modern fever hospital contains—(1) An administrative block for hospital staff, dispensary, kitchen, etc. (2) Separate pavilions for each disease to be isolated, and consisting of two wards, one for each sex. Wards of one story are recommended, but it would probably be better to have them of two stories, and then send the convalescents to the upper story. (3) Accessory buildings consisting of porter's lodge, mortuary, and post-mortem room, motor ambulance shed, laundry, boiler, engine rooms, and disinfecting house.

In the ward there should be 144 square feet of floor space and 2,000 cubic feet of air space for each patient. The floor should be of polished wood blocks laid on concrete. The walls should be covered for a distance of 4 or 5 feet from the floor with glazed tiles, and in any case should be impervious and washable. The upper parts of the wall and ceiling may be distempered.

Regulations of a fever hospital: (1) The nursing staff must change their outer clothing, which should consist of cotton material, before leaving the hospital; (2) the medical officers, students, and friends of patients, etc., should wear overalls on entering the wards, and should wash their hands on leaving; (3) convalescents should, as far as possible, be kept apart from the acute cases, and should before leaving take a hot bath and have their clothing disinfected.

The utility of fever hospitals has been questioned, and certainly in the case of Scarlet Fever their introduction has led to no apparent reduction in the incidence of this disease. It is even held by some that complications are more frequent and more serious in cases of this disease treated in hospital than in

cases treated at home. The cause of this occurrence must be attributed to insufficient isolation of the patients in the ward. There is no doubt that the principle of isolation is right, but care must be taken that it is carried out thoroughly in practice. Another objection to isolation hospitals is that "return" cases occur after the patient returns home. This has been most noticeable in the case of Scarlet Fever. To prevent this untoward result, the convalescents should be kept apart from the sick, should have their throats treated with disinfectants daily, and should have their clothing disinfected immediately before leaving.

The importance and benefit of the isolation in hospital of cases of Smallpox and Typhus has never been questioned, and there are no arguments against, but everything in favour of, the treatment of Diphtheria and Enteric Fever in hospital. In a hospital there is at hand every facility for dealing with the complications which may occur in these diseases—*e.g.*, for Tracheotomy or Intubation in Laryngeal Diphtheria, or Laparotomy in the case of a Perforated Ulcer in Enteric Fever.

The Midwives Act, 1902, established the Central Midwives Board, consisting of nine members, four of whom are medical men. The duties entrusted to this Board include the forming of rules regulating the issue of certificates, the courses of training, the conduct of examinations for certificates and the practice of midwives, including their suspension and the removal of their names from the roll for neglect of rules. The rules of the Central Midwives Board among other points prescribe:

1. Scrupulous cleanliness on the part of the midwife.
2. The boiling of instruments and appliances.
3. Thorough disinfection of instruments, clothing, and person after attendance on a septic case.
4. The calling in of medical assistance when the patient, during pregnancy or labour, presents certain specified symptoms, or when the child presents any abnormality, any inflammation of the eyes, however slight, serious skin eruptions, or inflammation about the navel.

By the Registration Acts the father or mother must give notice to the registrar within forty-two days of the birth of a

child, and must sign the register in his presence. This Act does not apply to stillbirths. With the object of diminishing infantile mortality, the Notification of Births Act, 1907, was passed. This is an adoptive act; where adopted, the birth of any child born after the expiration of the twenty-eighth week of pregnancy, whether alive or dead, must be notified to the Sanitary Authority within thirty-six hours. On receipt of the notification the house is visited by a health visitor—a woman who, from having acquired a special training, is able to instruct the mother in matters pertaining to the care and nurture of herself and child; at the same time insanitary conditions may be recognized, and, if possible, remedied.

The National Insurance Act, 1911, by providing thirty shillings Maternity benefit in cases of confinement of the wife of an insured person, or of a woman who is herself an insured person, should tend to provide a better environment for the mother and child. The Children Act, 1908, deals with—

1. Infant life protection.
2. Prevention of cruelty to children.
3. Cleansing of verminous children.

The Cleansing of Persons Act, 1897, gives power to Sanitary Authorities to provide cleansing facilities free of charge to persons invested with vermin. At the public disinfecting station baths are erected for the purpose, and whilst the person is being bathed the clothes are disinfected. For dealing with the "contacts" in outbreaks of Typhus Fever, such provisions are indispensable.

CHAPTER XIX

SANITARY LAW

State medicine as an organized department of administration is entirely of modern growth, having its inception in the third decade of the nineteenth century.

In 1834 the Poor Law Board was established, its function being to supervise the manner in which the local boards for each district discharged the duties (connected with the public relief of the poor) entrusted to them. Here we have a principle established which is at the basis of all the public health administration of England—local control subject to the supervision of a central authority. The English with all their love for self-government with regard to local affairs recognize that a central authority is necessary for correlating and comparing the experience of the various local authorities, for acting as a court of appeal, and for interfering when a local authority appears to be negligent of the duties entrusted to it. In 1836 the General Register Office was established with the Registrar-General at its head, and the registration of births, marriages, and deaths was instituted. From this date England had the means of obtaining exact data with regard to the vital statistics of the country, a decennial census having been taken since 1801. In 1838, the first report of the Registrar-General appeared, and in the same year the Poor Law Board issued their report on the sanitary condition of the labouring population of Great Britain. This report called public attention to the insanitary state of the country generally, and a Commission was appointed to inquire into the causes of the evils revealed in the report. This awakened interest in public health led many communities to obtain from Parliament power to deal with the insanitary conditions prevailing in their districts. Ten years after the issue of the report public opinion had been sufficiently educated to enable Parliament to pass the Public Health Act, 1848. The

provisions of this Act applied to the whole of England, with the exception of London. This Act created a General Board of Health as the supreme authority in sanitary matters, but greater local sanitary control was given by an Act of 1858.

The Local Government Board, the present central authority, was created by an Act of 1871, and took over all the powers and duties vested in or imposed on the Poor Law Board, which now ceased to exist. Numerous Acts dealing with public health were passed from 1849 to 1875, but in the latter year these various measures were consolidated by a Public Health Act, which forms a very precise sanitary code. From time to time new Acts dealing with public health are placed on the Statute Book, and in accordance with the Act of 1875 the administration of them rests in the hands of a central authority, the Local Government Board, and local authorities, the District Councils.

On the whole, the sanitary regulations are very similar in England, Wales, Scotland, and Ireland, although some slight differences exist in their sanitary organizations. In all three the Local Government Board of each is the central authority. In England and Wales the Local Government Board, as constituted by the Local Government Act of 1871, consists of a political President, appointed by the Crown, and certain *ex-officio* members—viz., the Lord-President of the Privy Council, all the principal Secretaries of State, the Lord Privy Seal and the Chancellor of the Exchequer, a Parliamentary Secretary, and a Permanent Secretary. The President and Secretaries direct the operations of the Board; the other members only take part in matters of special importance. Under the Permanent Secretary are five Assistant Secretaries, each of whom has charge of one of the departments into which the Board is divided for convenience of administration: (1) Poor Law; (2) Public Health, including Vaccination, Local Finance, Local Acts; (3) Audit of Accounts of Local Authorities, Statistics, and Local Taxation; (4) Loans, Housing, and Town-Planning; (5) Legal Matters—*e.g.*, By-laws, questions of law relating to administration of Local Government and Poor Laws, Old-Age Pensions, Provisional Orders, etc.

The Board is assisted in its deliberations by engineering and medical experts. The Medical Department consists of the

Medical Officer to the Board, two assistant Medical Officers, and a staff of Medical Inspectors. The inspectors (general, medical, and engineering) are the eyes and ears of the Board in the provinces.

The constitution of the Scotch and Irish Local Government Boards is somewhat different, but the duties and powers are very similar to those of the English Board.

Sanitary Areas and District Councils.—The whole of England and Wales outside the county of London (which is divided into twenty-eight Metropolitan boroughs), is divided into (1) administrative counties, and (2) county boroughs. By the Local Government Act, 1894, the administrative counties are divided into urban and rural districts. For sanitary administration the county boroughs rank as urban districts, and with the other urban districts constitute urban sanitary districts; while the rural districts, each consisting of one or more parishes, are rural sanitary districts. For the purposes of local government, including public health, councils, the members of which are elected by popular vote, are formed for the various sanitary areas. Thus, for the county, the urban, and rural districts, the local Sanitary Authorities are respectively the County Council, the Urban District Council, and the Rural District Council. In county boroughs and municipal boroughs which are also urban districts, the Mayor and aldermen and burgesses, in the former case, and the municipal council in the latter, are the local authority. In rural districts the existence of parish councils allows the needs of the district to be considered by those most conversant with them. The duties of the parish councils are mainly concerned with the questions of water-supply and drainage, the rural Sanitary Council being the real responsible Sanitary Authority for the district. The administration of the Public Health Acts rests mainly with the urban and rural district councils, the duties of the county councils being mainly supervising. The county councils, however, administer the Isolation Hospital Acts, the Rivers Pollution Prevention Acts, the Diseases of Animals Acts, the Midwives Act, appoint county coroners, and make by-laws with regard to various sanitary matters, in drawing up which they are guided by the Medical Officer of Health of the county.

Sanitary Officials and their Duties.—For carrying into effect the provisions of the various Public Health Acts, every Sanitary Authority has to appoint a medical officer of health and at least one sanitary inspector. In the larger urban districts there is necessary a large staff of inspectors, directed in their operations by the medical officer of health. In the matter of sanitary engineering and architecture the surveyor affords to the Sanitary Authorities the necessary expert knowledge; but on the question of the influence of the various engineering undertakings on health, the medical officer of health is the advising officer. For the office work the larger urban districts provide a sufficient clerical staff. With the medical officer of health and the sanitary inspectors rests the practical administration of the Public Health Acts, and according to their efficiency and zeal, or inefficiency and indifference, is determined in great measure the sanitary condition of the district. If these officers are progressive in their sanitary ideas, they are liable to make enemies of the owners of insanitary property.

It is now becoming evident that, for the proper administration of the sanitary statutes, it is necessary for the medical officer of health (1) to have security of tenure of his office, (2) to be a full-time officer.

To be eligible for the post of a medical officer of health the candidate must be a registered medical practitioner, and if the appointment is to a district with a population of 50,000 inhabitants or more, he must possess a diploma in public health.

It is impossible in this short chapter to give in detail the provisions of the Acts dealing with public health. The names of the principal Acts and their general scope merely are indicated. The Public Health Act, 1875 (1878 of Ireland), contains sections relating to sewers, house drainage, excrement and refuse disposal, scavenging and cleansing, water-supply, cellar dwellings, common lodging-houses, nuisances, offensive trades, unsound food, infectious diseases, hospitals, mortuaries, new streets and buildings, slaughter-houses, etc. It also empowers a Sanitary Authority to make by-laws and regulations in respect of certain matters. By-laws are designed to supplement, not to summarize, vary, or supersede, the express pro-

visions of the statute law. Before becoming valid, by-laws require the sanction of the Local Government Board; but this is not necessary in the case of most regulations. A breach of a by-law renders the offender liable to a penalty. Penalties are not usually attached to regulations. Every Sanitary Authority must make by-laws as to common lodging-houses, and every urban Sanitary Authority must do the same with regard to slaughter-houses.

Important powers in the interests of sanitation and hygiene are given by this Act to Sanitary Authorities, in order to abate any nuisance in their district. The Act defines the following to be nuisances: (1) Any premises, including buildings or lands, in such a state as to be a nuisance or injurious to health. (2) Any pool, ditch, gutter, watercourse, privy, urinal, cesspool, drain, or ashpit, so foul or in such a state as to be a nuisance or injurious to health. (3) Any animal so kept as to be a nuisance or injurious to health. (4) Any accumulation or deposit which is a nuisance or injurious to health. (5) Any house, or part of a house, so overcrowded as to be dangerous or injurious to health of the inmates, whether or not members of the same family. In interpreting the term "overcrowded," a medical officer of health is usually guided by the minimum standards laid down by the Local Government Board in their model by-laws—namely, 400 cubic feet for rooms in which persons both live and sleep, and 300 cubic feet for rooms used solely as workplaces. (6) Any factory, workshop, or workplace not kept in a cleanly condition, or not ventilated in such a manner as to render harmless as far as practicable any gases, vapours, dust, or other impurities, generated in the course of the work carried on therein that are a nuisance or injurious to health, or so overcrowded as to be dangerous or injurious to the health of those employed therein. (7) Any fireplace or furnace which does not as far as practicable consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any manufacturing or trade process whatever; and any chimney (not being the chimney of a private dwelling-house) sending forth black smoke in such quantity as to be a nuisance.

The offensive trades mentioned in the Act are those of blood-

boiler, bone-boiler, fellmonger, soap-boiler, tallow-melter, tripe-boiler, and any other noxious or offensive trade, business, or manufacture. The consent of an urban Sanitary Authority is required before an offensive trade can be established in their district, and the Sanitary Authority can make by-laws to prevent or diminish nuisance arising from those already established.

In the following paragraphs a brief account is given of the powers possessed by a Sanitary Authority with regard to water, unsound food, milk, sale of food and drugs, prevention of pollution of rivers, and housing. The chief provisions of the enactments dealing with the prevention of disease and factories and workshops are considered in separate chapters.

Water-Supply.—By the Public Health Act, 1875, the duty of providing a district with a sufficient supply of wholesome water devolves upon the Sanitary Authority, unless this has already been undertaken by a water company provided with Parliamentary powers. Any Sanitary Authority may construct works for supplying any part of their district with water, or may hire or purchase such works or contract for the supply. The Public Health (Water) Act, 1878, enacts that every occupied dwelling-house in a rural district has within reasonable distance an available and sufficient supply of wholesome water.

Unsound Food.—The medical officer of health or inspector of nuisances may at all reasonable times examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, exposed for sale or deposited for the purpose of sale or of preparation for sale, and intended for the food of man, and may seize the same if diseased, unsound, or unwholesome, and take it to a magistrate, who may order it to be destroyed, and inflict a penalty upon the offender. By the Public Health Acts Amendment Act, 1890, these powers are extended so as to deal with any article of food. The Public Health (Regulations as to Food) Act, 1907, gave power to the Local Government Board to issue regulations for the prevention of danger arising to public health from the importation, storage, preparation, and distribution of food or drink (other than drugs or water) intended for sale for human consumption. The Sale of Food and Drugs Act, 1875, has for its main object

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the prevention of adulteration of food. Among its provisions are the following: (1) No person shall mix, colour, stain, or powder any article of food with any ingredient or material so as to render the article injurious to health. (2) No person shall sell to the prejudice of the purchaser any article of food or any drug which is not of the nature, substance, and quality of the article demanded by such purchaser under a penalty not exceeding £20. (3) No person shall (with the intent that the same may be sold in its altered state without notice) abstract from an article of food any part of it so as to affect injuriously its quality, substance, or nature.

Public analysts are appointed to carry out the necessary analysis and take as their standards with which to compare their results those fixed by the Board of Agriculture. **Milk** can be seized by the medical officer of health or sanitary inspector if it is unsound under powers given by the Public Health Act, 1875, and samples can be taken for analysis under Sale of Food and Drugs Acts; but the orders issued by the Local Government Board under the Contagious Diseases (Animals) Acts are most important in controlling the trade. These Orders are administered by the local Sanitary Authority, and provide for—(1) the registration with the local authority of all persons carrying on the trade of cowkeepers, dairymen, or purveyors of milk; (2) the inspection of cattle in dairies, and for prescribing and regulating the lighting, ventilation, cleansing, drainage, and water-supply of cowsheds and dairies; (3) securing the cleanliness of milk-stores, milk-shops, and of milk-vessels. (4) Prescribing precautions against infection or contamination of milk. Section 15 of the Dairies, Cowsheds, and Milkshops Order prescribes that the milk of a cow suffering from cattle plague, pleuro-pneumonia, foot-and-mouth disease, and tuberculosis (*a*) shall not be mixed with other milk; (*b*) shall not be sold and used for human food; and (*c*) shall not be sold or used for the food of animals, unless it has been boiled. (5) The issue of regulations by the local Sanitary Authority for any or all of the aforesaid purposes.

The Rivers Pollution Prevention Act, 1876, aims at the prevention, as far as practicable, of the contamination of streams by solid matters, sewage, trade effluents, and mining effluents.

Housing.—It has already been pointed out that insanitary premises may be dealt with as nuisances under the Public Health Act, 1875. The Housing of the Working Classes Act, 1890, enables a Sanitary Authority to deal with (1) unhealthy areas; (2) unhealthy or obstructive dwellings; and (3) to provide lodging-houses for the working classes, and to make by-laws for their regulation.

The Housing, Town-Planning, etc., Act, 1909, gives increased powers and facilities to authorities to provide houses for the working classes, and to close and demolish dwellings unfit for habitation. The erection of back-to-back houses is prohibited. The town-planning part of the Act enables local authorities and landowners to co-operate in the preparation of plans, so that in future land in the vicinity of towns shall be developed in such a way as to secure proper sanitary conditions, amenity, and convenience.

Duties of the Medical Officer of Health.

The student is now in a position to understand the duties of the medical officer of health, as prescribed in the Local Government Board's Order, 1910. This Order is given verbatim, as it shows how wide is the scope and how varied the nature of the work of public health administration.

1. He shall inform himself as far as practicable respecting all influences affecting or threatening to affect injuriously public health within the district.

2. He shall inquire into and ascertain by such means as are at his disposal the causes, origin, and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

3. He shall, by inspection of the district, both systematically at certain periods and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

4. He shall be prepared to advise the Council on all matters affecting the health of the district, and on all sanitary points involved in the action of the Council; and in cases requiring it he shall certify, for the guidance of the Council or of the justices, as to any matter in respect of which the certificate of a medical officer of health or a medical practitioner is required as the basis or in aid of sanitary action.

5. On receiving information of the outbreak of any infectious or epidemic disease of a dangerous character within the district, he shall visit without

delay the spot where the outbreak has occurred, and inquire into the causes and circumstances of such outbreak, and in case he is not satisfied that all due precautions are being taken, he shall advise the persons competent to act as to the measures which appear to him to be required to prevent the extension of the disease, and shall take such measures for the prevention of disease as he is legally authorized to take under any statute in force in the district or by any resolution of the Council.

6. Subject to the instructions of the Council, he shall direct or superintend the work of the Inspector of Nuisances in the way and to the extent that the Council shall approve, and on receiving information from the Inspector of Nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall, as early as practicable, take such steps as he is legally authorized to take under any statute in force in the district, or by any resolution of the Council, as the circumstances of the case may justify and require.

7. In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the Council, he shall himself inspect and examine any animal, carcass, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour, or milk, and any other article to which the provisions of the Public Health Acts in this behalf apply, exposed for sale, or deposited for the purpose of sale or of preparation for sale, and intended for the food of man, which is deemed to be diseased, or unsound, or unwholesome, or unfit for the food of man; and if he finds that such animal or article is diseased, or unsound, or unwholesome, or unfit for the food of man, he shall give directions such as may be necessary for causing the same to be dealt with by a justice according to the provisions of the statutes applicable to the case. He shall also take such action as it may be necessary for him to take by virtue of the provisions of the Public Health (Regulations as to Food) Act, 1907, and any regulations made thereunder.

8. He shall perform all the duties imposed upon him by any by-laws and regulations of the Council, duly confirmed where confirmation is legally required, in respect of any matter affecting the public health, and touching which they are authorized to frame by-laws and regulations.

9. He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

10. He shall attend at the office of the Council, or at some other appointed place, at such times as they may direct.

11. He shall from time to time report in writing to the Council his proceedings, and the measures which may require to be adopted for the improvement or protection of the health in the district. He shall in like manner report with respect to the sickness and mortality within the district, so far as he has been able to ascertain the same.

12. He shall keep a book or books, to be provided by the Council, in which he shall make an entry of his visits, and notes of his observations

and instructions thereon, and also the date and nature of applications made to him, the date and result of the action taken thereon, and of any action taken on previous reports; and shall produce such book or books whenever required to the Council.

13. On Monday, the 9th January, 1911, and on every Monday thereafter, he shall forward to the Local Government Board by post at such an hour as in the ordinary course of post will insure its delivery on the following Tuesday morning a return, in such form as the Local Government Board may from time to time require, as to the number of cases of infectious disease notified to him during the week ended on the preceding Saturday night. He shall also forward at the same time a duplicate of the return to the medical officer or officers of health of the county or counties in which the district is situated.

14. He shall as soon as practicable after the 31st December in each year make an annual report to the Council up to the end of December, on the sanitary circumstances, the sanitary administration, and the vital statistics of the district.

In addition to any other matters upon which he may consider it desirable to report, his annual report shall contain the information indicated in the following paragraphs, together with such further information as the Local Government Board may from time to time require:

(*a*) An account of any influences threatening the health of the district, the prevalence of infectious or epidemic diseases therein, and the measures taken for their prevention.

(*b*) An account of all general and special inquiries made during the year.

(*c*) An account of the work performed by the Inspector of Nuisances during the year, including the statement supplied in pursuance of Article XX. (16) of this Order.

(*d*) A statement as to the conditions affecting the wholesomeness of the milk produced or sold in the district.

(*e*) A statement as to the conditions affecting the wholesomeness of foods for human consumption, other than milk, produced or sold in the district.

(*f*) A statement as to the sufficiency and quality of the water-supply of the district and of its several parts, and in areas where the supply is from waterworks, information as to whether the supply is constant or intermittent.

(*g*) A statement as to the pollution of rivers or streams in the district.

(*h*) A statement as to the character and sufficiency of the arrangements for the drainage, sewerage, and sewer disposal in all parts of the district.

(*i*) A statement as to the privy, water-closet, and other closet accommodation in the district, including information as to the approximate number of each type of privy and closet.

(*j*) A statement as to the character and efficiency of the arrangements for the removal of house-refuse, and the cleansing of earth-closets, privies, ash-pits, and cesspools, in the district.

(*k*) A statement with regard to the housing accommodation of the district, as required by Article V. of the Housing (Inspector of District) Regulations, 1910, and an account of any other action taken by the Council under the Housing, Town Planning, etc., Act, 1909, bearing on the public health.

(*l*) A statement as to the vital statistics of the district, including a tabular statement, in such form as the Local Government Board may from time to time direct, of the sickness and mortality within the district.

(*m*) Where the Medical Officer of Health is appointed by the Council of a county borough, or by a Council having delegated powers under the Midwives Act, 1902, a statement as to the administration of that Act in the district.

15. He shall forthwith report to the Local Government Board any case of plague, cholera, or smallpox, or of any serious outbreak of epidemic disease in the district which may be notified to him, or which may otherwise come or be brought to his knowledge.

16. He shall transmit to the Local Government Board three copies of each annual report and one copy of any special report. At the same time he shall transmit a copy of the report or give the like information to the County Council or County Councils of the county or counties within which the district is situated. Where the Medical Officer of Health is appointed by the Council of a county borough, or by a Council having delegated powers under the Midwives Act, 1902, he shall also transmit to the Privy Council and to the Central Midwives Board either a copy of his annual report, or of that part of it which contains the statement relating to the administration of the Midwives Act, 1902.

17. In matters not specially provided for in this Order he shall observe and execute any instructions issued by the Local Government Board, and the lawful orders and directions of the Council applicable to his office.

18. Whenever the Local Government Board shall make regulations, and shall declare the regulations so made to be in force within any area comprising the whole or any part of the district, he shall observe such regulations, so far as the same relate to or concern his office.

If in the above account the words "ships" and "shipping" within the district are substituted for "houses" and "district," the duties prescribed by the Local Government Board for a medical officer of health to a port Sanitary Authority will be indicated.

CHAPTER XX

VITAL STATISTICS

The progress of hygiene can be gauged from statistics relating to the morbidity or mortality experienced by a community or country. Up to the present, however, information with regard to the amount of sickness prevailing in a district is not comparable as regards fulness and accuracy with the death returns. The operations of the National Insurance Act (1911) will in time fill up many of the blanks in our vital statistics.

The chief facts with regard to the health of this country can be ascertained from—

1. The annual reports of medical officers of health. These give particulars regarding the notifiable infectious diseases.
2. The reports of the Registrars-General for England and Wales, Scotland, and Ireland.
3. Reports of the Medical Officer to the Local Government Board of England and Wales, Scotland, and Ireland.
4. Reports of the Medical Officer of Board of Education.
5. Reports of Chief Inspector of Factories.
6. Census returns.

Since 1801 a decennial census has been taken in the United Kingdom. At the present time the census returns show the number of inhabitants in the different areas into which the country is divided, the number living of each sex and at certain age-periods, the numbers engaged in various occupations, and the number of blind, deaf and dumb, imbecile, and lunatic.

The census is taken in the first week of April, but death-rates, etc., are calculated on the population alive at the middle

of the year, so that even in the census year an estimate of the mid-year population has to be made. In intercensal years estimates of the population of the country and its registration areas are made by the Registrars-General.

In a country like England, where the births have for a great number of years exceeded the loss caused by death and emigration, there is a steady increase of population. In Ireland, as a result of emigration, the population has declined; in 1901 it was 4,458,775, and in 1911, 4,390,219.

In estimating the population of a country, use is made of what has been called the "law of population," according to which a population increases in regular geometrical progression when the births exceed the deaths and the ratio of the births and of the deaths to the population remains constant. According to the census of 1911, the total population of England and Wales on April 3, 1911, was 36,070,492. On the assumption of a continuance of increase by geometrical progression at the rate experienced during 1901-1911, the Registrar-General estimated the population at the middle of the year 1911 to have been 36,163,833 ; and on the further assumption of a continuance in arithmetical progression of the change in the population of the sexes experienced between the last two censuses, this total is estimated to have been made up of 17,490,847 males and 18,672,986 females. The Registrar-General of England and Wales has supplied the following factors for calculation of estimates of population:

1911 ..	.. 0·02634780	1916 ..	.. 0·56787619
1912 ..	.. 0·13242746	1917 ..	.. 0·67958101
1913 ..	.. 0·23960799	1918 ..	.. 0·79244797
1914 ..	.. 0·34790096	1919 ..	.. 0·90648664
1915 ..	.. 0·45731880	1920 ..	.. 1·02170833

The population of any district at the middle of any year from 1911-1920 is calculated by adding to the population enumerated in 1911 the product of the increase of population in the last intercensal period and the factor for the year in the above series. In the case of a decreasing population, the product of the intercensal decrease multiplied by the factor should be deducted from the population enumerated in 1911. The factors have been obtained from the equation $\frac{Pt-P_1}{P_1-P_0}$, where

Pt stands for the population (however estimated) of the country as a whole at an intercensal time, t, P_0 and P_1 for the enumerated population of England and Wales in 1901 and 1911. It is obvious that the factor increases as the year for which the population is to be determined approaches a new census year.

An example will make the estimation clearer. The population of the extended city of Birmingham was 759,063 in 1901, and 840,202 in 1911, the increase in the intercensal period having been 81,139. The estimated population of the city at the middle of the year 1916 is therefore—

$$840{,}202 + 81{,}139 \times 0{\cdot}56787619 = 886{,}278.$$

Age and Sex Distribution.—The census returns show the number of persons of each sex living at the twelve age-periods comprised as follows: (1) Under 5 years; (2) 5 to 10; (3) 10 to 15; (4) 15 to 20; (5) 20 to 25; (6) 25 to 35; (7) 35 to 45; (8) 45 to 55; (9) 55 to 65; (10) 65 to 75; (11) 75 to 85; (12) over 85. In contrasting the vital statistics of one district with another, cognizance must be taken (1) of the age and sex distribution of the respective populations, since that population which has an undue proportion of persons at the extremes of life will be unfavourably situated as compared with a town where there are many persons in their prime; and (2) of the fact that, except at the age-periods 5 to 10 and 10 to 15, males suffer a higher mortality than females. The mean ratio of males per cent. of female mortality at the various age-periods during the years 1901-1910 has been shown by the English Registrar-General to be as follows:

Years of Age.											
0	5	10	15	20	25	35	45	55	65	75	85
119	97	95	107	120	119	123	130	128	120	115	112

The excess of the mortality of males in infancy and from phthisis, pneumonia and violence together amount to more than the total excess from all causes, which would have been

32 per cent. greater than it actually was but for the mortality of females from child-bearing and from cancer of the generative organs, causes peculiar, or almost so, to the female sex.

The excess of mortality of males during the last fifteen years has averaged about 14 per cent.

Marriages.—The marriages in England and Wales during the year 1911 numbered 274,943 in an estimated population of 36,163,833. It is usual to express returns as regards marriages, births and deaths, as a rate of so many per 1,000 of the total population living. Thus, to calculate the marriage-rate, knowing the number of weddings and the total population, is a mere matter of simple proportion, and is found from the following equation:

$$\frac{\text{Number of marriages}}{\text{Population}} \times 1{,}000.$$

In 1911 the corresponding figures were—

$$\frac{274{,}943}{36{,}163{,}833} \times 1{,}000 = 7{\cdot}6.$$

The English Registrar-General expresses his returns as persons married per 1,000, and this, of course, is double the marriage-rate; in the above instance it is 15·2.

In Ireland the average annual marriage-rate during the decennium 1901-1911 has been 5·1. Ireland's low rate is due to emigration.

The age at which women marry has an important effect on the birth-rate, child-bearing being limited practically to between the sixteenth and forty-fifth year of life. The mean age at marriage has been gradually rising since 1873; in 1911 the mean age of husbands was 29, and of wives 26·8.

Birth-Rates. By the Births and Deaths Registration Act, 1874, every birth must be registered within forty-two days of its occurrence. Still-births are not registered. Registration of births is quite distinct from, and is in no way affected by, the notification given in districts where the Notification of Births Act, 1907, has been adopted. In the latter case the information is not forwarded to the Registrar-General, but is required to be sent to the local Sanitary Authority within thirty-six hours after the birth.

The birth-rate is usually expressed as so many births per 1,000 of the general population. The total number of births and the population being known, it is calculated by simple proportion. In 1911 there were 881,138 births in England and Wales in a population of 36,163,833. The birth-rate, therefore, for that year was—

$$\frac{881,138}{36,163,833} \times 1,000 = 24{\cdot}4.$$

The highest birth-rate recorded in England was 36·3 in 1876, and since that date there has been a gradual decline. In order to gauge the fertility of a country, it is necessary to calculate the following proportions:

1. Of total births to the total population of both sexes and all ages.
2. Of total births to the female population aged 15 to 45 years.
3. Of legitimate births to the married female population aged 15 to 45 years.
4. Of illegitimate births to the unmarried and widowed female population aged 15 to 45 years.

These calculations have been made by the English Registrar-General, and have been found for the groups 1, 2, 3, 4, to be in 1911, 24·4, 97·8, 196·2, and 8 per 1,000 respectively. "The fall in the legitimate birth-rate since 1876-1880 is 10·34, and this net fall must be made of a potential rise of 1·56, due to increased proportion of wives aged 15 to 45, and a fall of 11·90, due to the diminished fertility of wives." This diminished fertility, in the opinion of the English Registrar-General, is due in some measure to their greater average age, but largely to deliberate restriction of child-bearing.

A declining birth-rate is noted in practically every civilized country. It commenced first in France, is now well-marked in England and United States, and is beginning in Germany. Publicists on social questions are divided as to their opinions on the decline of the birth-rate ; some view it with alarm, regarding it as a sign of racial degeneracy, others as a result which makes for the comfort and well-being of the children

born, since greater efforts will be made for their conservation. If Karl Pearson's view is true, that the fall in the birth-rate is due to the relative infertility of the most valuable stocks in the race, then this becomes a question of national importance.

Death-Rates.—By the Births and Deaths Registration Act of 1874 all deaths must be registered within five days of their occurrence. In England and Wales 527,810 deaths were registered in 1911, which is a rate of 14·6 per 1,000 of the population living. In 1912 the rate was 13·3. There has been a marked decline in the death-rate during the last twenty years. For the decades 1841-1850, 1851-1860, 1861-1870, 1871-1880, the average rate was 21, so that there has been a reduction to two-thirds of the former rate.

Correction of Death-Rates for Differences of Sex and Age Constitution of Population.—Women live longer than men, and at age-periods between 5 and 55 in the case of both sexes, there is a lower mortality than that found among children under 5 and adults over 55. Before comparing one district with another as regards mortality, the crude death-rate must be altered so as to make allowance for the difference in the age and sex constitution of the population. Two methods have been employed for this purpose—the "direct" and the "indirect." The following quotations from the seventy-fourth Annual Report of the English Registrar-General (1911) explain the two procedures: "By the direct method we take one million persons, grouped as to sex and age, as was the population of England and Wales in 1901, and, applying to each of the (eleven or more) age-groups in each sex, the mortality experienced during the year by the corresponding group of the population in question, calculate the total number of deaths which would have resulted had each section of this million persons died at the same rate as did the same section of the population dealt with during the year in question. The result known as the corrected, or preferably the standardized, death-rate forms a statement of mortality which accurately summarizes the tendency to death of each sex and age group of the population concerned, and is, of course, strictly comparable with similarly prepared statements relating to any other populations, however differently constituted."

The populations elected should be as typical as possible of the bulk of those to be compared. The population of England and Wales in 1901 seems to comply with this condition, and, in fact, has also been adopted by the United States Census Bureau.

" The direct method gives slightly more accurate results than the indirect, but is very laborious; hence the latter method is commonly employed. By the ' indirect ' method of standardization the favourable or unfavourable nature of a population's sex and age distribution in relation to mortality is first assessed, and then the recorded mortality is increased or diminished, in order to compensate for the advantage or disadvantage so disclosed. The method is, in fact, a method of handicapping. Populations which, from their favourable constitution, enjoy an advantage in comparison with the standard population (England and Wales, 1901) have their mortalities increased by a handicap in the form of a ' standardizing factor,' while the mortalities of unfavourably constituted populations are diminished in the same way. The handicap, or factor, once determined, necessarily remains constant until a new census (or alteration of boundaries) reveals a change in the constitution of the population concerned, and therefore the labour involved is much less than by the direct method, the calculations for which require to be made afresh each year."

" The method of ascertaining the required handicap is as follows: The mean death-rates for England and Wales during 1901-1910 at certain age-groups for males and females respectively are applied to the numbers enumerated at the latest census at the corresponding ages in the case of the population in question; the sum of the products gives the deaths that would have occurred in a year had the mortality of each sex and age group been the same as that in England and Wales as a whole, and the death-rate obtained by applying this sum to the population in question as enumerated at the census, formerly known as the ' standard death-rate,' but now, in view of the adoption of the term ' standardized death-rate,' better described as the ' index death-rate,' indicates the degree to which that population is favourably or unfavourably consti-

tuted. If the population contains a high proportion of persons at the ages at which mortality in England and Wales exceeds that of persons at all ages, its index death-rate will be high, as under the converse conditions it will be low."

"The mortality-rates for England and Wales during 1901-1910, then, represent the foot-rule by which the constitution of each population is measured, and the index death-rate the reading in each case of this measure. When this reading has been taken, the required handicapping is performed by comparing it with the index death-rate for the population of England and Wales in 1901, calculated in the same way. If the index death-rate of the area dealt with is high, the constitution of its population is unfavourable, and its recorded mortality must be proportionately reduced by a handicap, or 'standardizing factor,' which is obtained by dividing the index death-rate for England and Wales in 1901 by the (higher) index death-rate of the population in question, and is therefore necessarily less than unity. Where the index death-rate is low, indicating a favourable constitution, the factor is greater than unity, and when multiplied into the recorded death-rate, increases it. The result in either case is termed the 'standardized death-rate.'"

The effect of age on mortality is seen in a comparison of the standardized death-rates at twelve groups of ages and infantile mortality, as given in Table 13 of the Report of the English Registrar-General for 1911:

Year.	Deaths of Persons per 1,000 living at Subjoined Ages.													Deaths of Infants under 1 Year per 1,000.
	All Ages standardized.	0.	5.	10.	15.	20.	25.	35.	45.	55.	65.	75.	85 and upwards.	
1841-50	21·5	66	9·0	5·3	7·5	9·3	10·3	12·9	17·0	29·9	63·6	141·5	301·0	153
1901-10	15·2	46	3·6	2·1	3·0	3·8	5·1	8·3	14·3	28·1	58·8	127·2	260·8	128

Infantile Mortality.—The infantile mortality is the annual number of deaths of infants under one year of age to every 1,000 births during the same year. Of the 527,810 deaths registered during 1911 in England and Wales, 114,600, or

21·7 per cent., were those of infants under one year of age, corresponding to a mortality-rate of 130 per 1,000 births.

$$\frac{\text{Number of deaths of children under 1 year, 114,600}}{\text{Number of births registered during year, 527,810}} \times 1{,}000 = 130 \text{ per } 1{,}000.$$

In 1910 the rate was 105, the increase in 1911 being due to a high mortality from Infantile Diarrhœa, caused by the exceedingly dry summer. In fact, in 1911 Diarrhœa and Enteritis caused 28 per cent. of the total infantile mortality; whereas in 1910, when the summer was cool and wet, the proportion so caused was only 12 per cent. To this slaughter of infants the percentage contributions of certain diseased conditions are as follows: Atrophy, Debility, and Marasmus, 12 per cent.; congenital defects, 3 per cent.; premature birth, 15 per cent.; Diarrhœa and Enteritis, 12 to 28 per cent.; Bronchitis and Pneumonia, 14 per cent.; Convulsions, 14 per cent.; Tuberculosis, 3 per cent.; and Whooping-Cough, 3 per cent. The mortality of illegitimate infants is about twice as great as that of the legitimate.

The mortality of male infants is, on an average, 21 per cent. greater than that of females.

In determining whether a child shall live or die, the mother plays the leading rôle. The mortality of breast-fed children is enormously less than that of those that are artificially fed. Instruction of mothers with regard to the care and feeding of children, as well as the progress of municipal sanitation, will in time reduce to proper limits the death-rate of young children. In a section on Infantile Mortality contributed by Dr. Stevenson to the Report of the English Registrar-General for 1911, statistics of infant mortality in the chief occupations and groups of occupations are given. Among the families of clergymen in 1911 the infantile mortality per 1,000 births was only 48; of army officers, 44; of naval officers and solicitors, 41; of medical practitioners, 39; and the rate of infant mortality of the middle classes generally was only 61 per cent. of the total mortality-rate of the country among legitimate infants.

With these figures may be compared the rate of infant mortality among general labourers of 167; ironworkers, 172; flax and hemp workers, 184; tin-miners, 190; costers and hawkers, 196.

In the following table is given the chief facts of the vital statistics of the United Kingdom of Great Britain and Ireland for the year 1911:

Population	45,297,114
Marriages	14·6 per 1,000
Births	1,104,707, or 24·4 per 1,000
Deaths	672,011, or 14·8 per 1,000
Infantile mortality	132 per 1,000 births
Mortality in army at home and abroad (strength, 243,414) ..	3·4 per 1,000
Rate at home	2·5
Rate abroad	4·4

Great reforms were introduced into the national vital statistics by the English Registrar-General in the Annual Report for 1911. These consisted in—(1) The administrative area being substituted for the registration as the local unit of tabulation for births and deaths, thus bringing the statistics in the Registrar-General's Report into line with the statistics contained in the annual reports of medical officers of health. (2) In the allocation as far as practicable of deaths to the area of residence. The number of such transferable deaths was about 40,000 in 1911, and includes deaths of persons in institutions for the sick and infirm, such as hospitals, lunatic asylums, workhouses, nursing homes, etc. (3) In the adoption of the international list of causes of death. (4) In the giving of a "standardizing factor" and a standardized death-rate for each sanitary area.

Cause of Death.—In order to effect registration of the causes of death, a death certificate is signed by the medical attendant, or, in case of an inquest, by the coroner. In this certificate "primary" and "secondary" causes of death are given. For example, where death has resulted from Broncho-Pneumonia supervening upon an attack of Measles, the primary cause of death is Measles, the secondary Broncho-Pneumonia.

The reports of medical officers of health contain information with regard to the following short list of causes of death approved by the Local Government Board and General Register Office: Enteric Fever, Smallpox, Measles, Scarlet Fever, Whooping-Cough, Diphtheria and Croup, Influenza, Erysipelas, Phthisis (Pulmonary Tuberculosis), Tuberculous Meningitis,

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PLATE XIII.

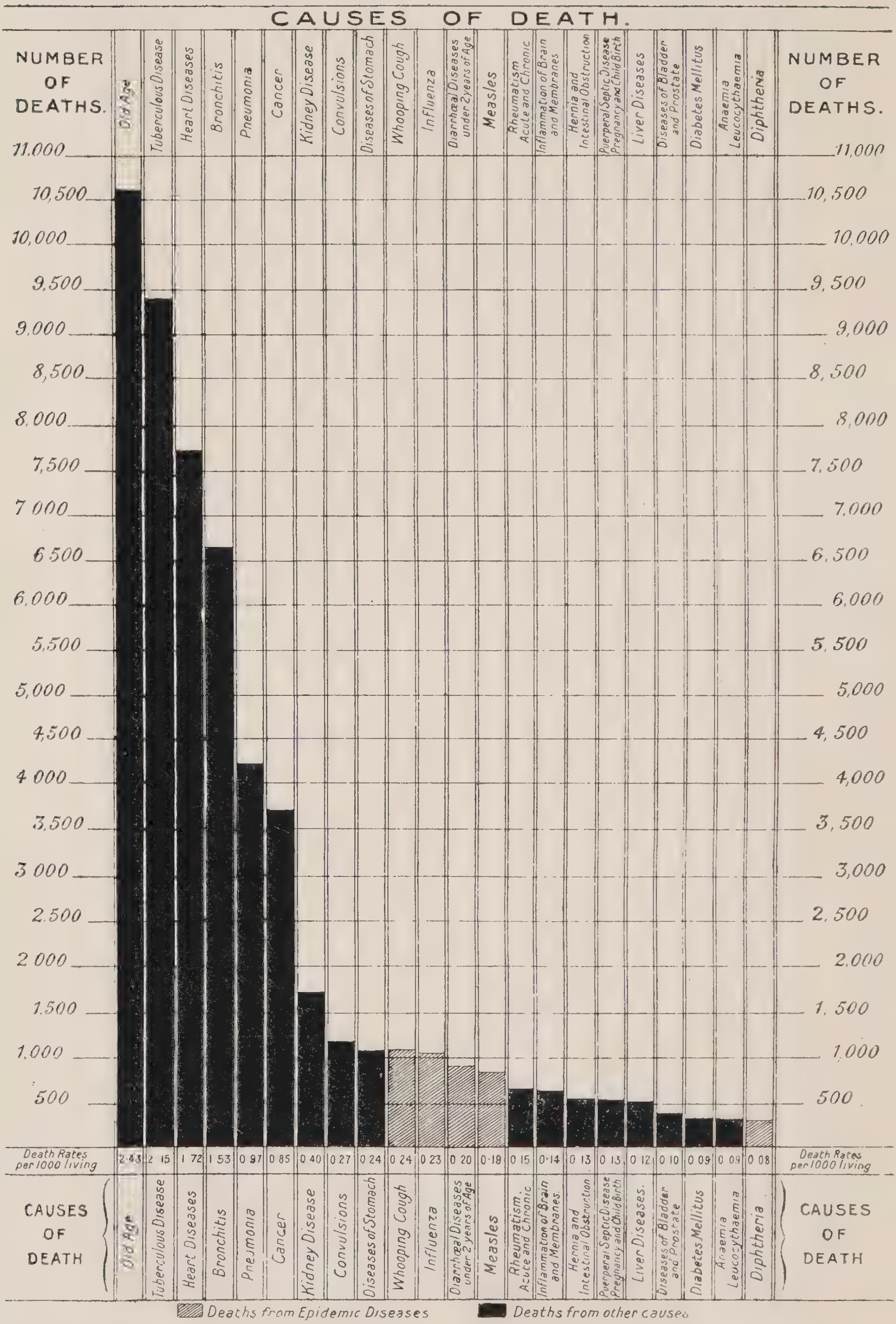

FIG. 26.—Mortality from Twenty-Two of the Principal Causes of Death in Ireland in year 1912.

(*From* Report of Irish Registrar-General, 1912.)

other tuberculous diseases, Cancer, Malignant Disease, Rheumatic Fever, Meningitis, organic Heart Disease, Bronchitis, Pneumonia (all forms), other diseases of respiratory organs, Diarrhœa and Enteritis, Appendicitis and Syphilis, Cirrhosis of Liver, Alcoholism, Nephritis and Bright's Disease, Puerperal Fever, other accidents and diseases of pregnancy and parturition, congenital debility and malformation (including premature birth), violent deaths (excluding suicides), suicides, other defined diseases, causes ill-defined or unknown.

The following table, taken from the English Registrar-General's Report for 1911, shows the amount of mortality due to the chief diseases:

Disease.	Proportion per 1,000 Deaths from all Causes.	Rate per 1,000 Living.
Measlse	24·9	0·36
Whooping-Cough	14·9	0·22
Diphtheria, Croup	9·5	0·14
Influenza	8·2	0·12
Phthisis, Pulmonary Tuberculosis	74·3	1·08
Other forms of Tuberculosis	26·3	0·38
Cancer	68·0	0·99
Diseases of nervous system and special sense	107·4	1·57
Organic Heart Disease	85·0	1·24
Other diseases of circulatory system	21·7	0·32
Bronchitis	69·4	1·01
Pneumonia	71·3	1·04
Other diseases of respiratory system	14·1	0·21
Diarrhœa and Enteritis	88·5	1·29
Other diseases of digestive system	38·9	0·57
Diseases of genito-urinary system	36·6	0·53
Premature birth and diseases of early infancy	65·8	0·96
Old age	65·8	0·96
Violence	38·5	0·56
Other causes	70·9	1·04
All causes	1,000·0	14·59

Fig. 26, taken from the Irish Registrar-General's Report, shows the chief causes of mortality in Ireland.

"Zymotic death-rate" was a term formerly applied to the aggregate death-rate from the "seven principal zymotic diseases"—Smallpox, Measles, Scarlet Fever, Diphtheria,

Whooping-Cough, "Fever" (Typhus, Simple Continued and Enteric), and Diarrhœa. It would probably be an advantage to discontinue the use of the term "zymotic" and to consider diseases due to specific micro-organisms as communicable diseases. At the present time the health of a district can be best judged from the rate-incidence of every communicable disease separately considered, rather than by taking the combined rate of a heterogeneous class.

It is evident from the preceding table that diseases of the circulatory, respiratory, and nervous systems are frequent causes of death. Of the 527,810 deaths occurring in England in 1911, Tuberculosis, Pneumonia, and Cancer are responsible for 53,120, 37,642, and 35,902 respectively. In the same period the number of deaths assigned to pregnancy and childbirth was 3,413, corresponding to a rate of 3·87 per 1,000 births; of these deaths, 1,262 were due to Puerperal Fever.

Dr. Newsholme has shown that, by comparing the experience of 1912 with the average experience of 1891-1900 in England, the rate of infant mortality has declined 38 per cent.; the death-rate from Measles, 16 per cent.; from Scarlet Fever, 66 per cent.; from Whooping-Cough, 40 per cent.; from Diphtheria and Croup, 57 per cent.; from Enteric Fever, 75 per cent.; from Tuberculosis (all forms), 32 per cent.; and from Pulmonary Tuberculosis, 25 per cent. Between 1891-1900 and 1911 the death-rate from puerperal diseases had fallen 28 per cent., from Pneumonia 15 per cent., and from Bronchitis 45 per cent.

The death-rate from all causes in England declined 27 per cent. between 1891-1900 and 1912.

Age in Relation to Mortality from Certain Diseases.—The maximum mortality from Smallpox, Whooping-Cough, Erysipelas and Diarrhœa occurs in the first year of life, from Measles in the second, from Scarlet Fever in the third, and from Diphtheria in the fourth. About three-fifths of deaths from Measles occur under two years of age. These facts show the importance of protecting children against infection during their earlier years.

Influence of Urban and Rural Life on Mortality.—The Registrar-General (1911) has shown that the standardized

mortality-rates in rural and urban districts are 11·3 and 15·2 respectively, and that town conditions tell more severely on males than on females, and on infants and the middle-aged and elderly than on children and the aged. The difference in the mode of life and social conditions account for the result. The density of the population in the town is an important factor; but it is not a question so much of the number of persons per acre as the number of persons per room, since Newsholme showed that the death-rate among the 20,000 inhabitants of Peabody Buildings (density, 750 per acre) was lower than that of London generally (density, 49 per acre).

Occupation and Mortality.—The most recent statistical investigation of this subject is that of Dr. Tatham in a supplement to the Seventy-Fifth Annual Report of the English Registrar-General, 1908. In this Report the data made use of are—(1) The number engaged in each occupation in 1901, as ascertained from the census; (2) the numbers lost by death at ages 25 to 65 in the three years 1900-1902, as shown by the registers of deaths. The mean of three years is taken as the average mortality.

In considering the influence of occupation on mortality, the time at which this influence is most exercised is usually taken to be between the twenty-fifth and sixty-fifth years of life. Separate tables are constructed for men and women.

"Among males generally between the ages of 25 and 65 years 1,000 deaths occurred annually among 71,005 living; if this latter number be divided proportionately to the numbers enumerated at the latter census, it will be found that 26,259 of them were living at ages 25 to 35 years, 20,407 at ages 35 to 45 years, 14,748 at ages 45 to 55 years, and 9,591 at ages 55 to 65 years. This number (71,005) has been adopted as the 'standard population,' which, subject to the rates of mortality obtaining in the several age-groups among males generally, produced 1,000 deaths annually. If the four constituent numbers above mentioned be multiplied by the death-rates recorded at the corresponding age-groups in each occupation, the sum of the products will give the number of deaths that would occur in the standard population, supposing it to have experienced the death-rates which prevailed in that occupa-

tion. This figure is called the 'comparative mortality figure' for the occupation. The method is exemplified in the following table, the occupation of farmer being taken as an illustration:''

Age Periods.	Standard Population.	All Males.		Occupied Farmers.	
		Annual Death-Rate per 1,000.	Deaths in Standard Population.	Annual Death-Rate per 1,000.	Deaths in Standard Population.
	(1)	(2)	(3)	(4)	(5)
25-35 years ..	26,259	6·38	168	3·96	104
35-45 ,, ..	20,407	10·94	223	5·66	116
45-55 ,, ..	14,748	18·67	275	10·05	148
55-65 ,, ..	9,591	34·80	334	20·25	194
25-65 years ..	71,005	—	1,000	—	562

The comparative mortality suffered from various diseases by those engaged in different occupations can be ascertained by multiplying the above "comparative mortality figure" by the fraction

$$\frac{\text{Deaths from specified cause at ages between 25 to 65}}{\text{Total deaths}}.$$

If this is done for phthisis, it will be found that of the 1,000 deaths from all causes in the standard population of 71,005, 186 are due to this cause; in the case of tin-miners, with a comparative mortality figure of 2,131, 816 deaths are due to this disease. The ratio of deaths from phthisis to total deaths shows, according to Professor Benjamin Moore, in a most interesting manner how the death-rate rises in those occupations where the workmen are most subjected to close contact with their fellows at the later and more infectious stages of the disease. In such occupations as that of printer, compositor, and lithographer, where the consumptive can go on with his work till near the end, one in every three dies of phthisis. Coal-miners have a death-rate from phthisis of only one in eleven, in spite of the dusty confined space in which they work; but here the severe physical labour compels the consumptive to stop mining before he becomes a severe menace to the health of his fellow-workmen.

The following list shows the comparative mortality figure for a few representative occupations:

All males	1,000
Clergymen	524
Teachers	665
Grocers	729
Solicitors	750
Carpenters	820
Physicians	952
Domestic servants	927
Hairdressers	1,196
Cutlers	1,566
Publicans	1,781
Tin-miners	2,131
General labourers	2,235

Statistical Criteria of the Health of a Community.—The standardized death-rate, the zymotic death-rate, infant mortality, and the phthisis death-rate, throw important light on sanitary and social conditions. By means of a life-table, information can be obtained with regard to the "probable duration of life" and the "expectation of life," the latter being generally regarded as the most valuable criterion of the health and longevity of a nation or city.

A life-table shows the number of survivors at each year of a definite number (usually 1,000,000) of people who start life together; its chief function is to show the expectation of life at any age, and this is calculated by adding together the years of life lived through by the whole of the life-table population after that age, and dividing this figure by the number of survivors at the age in question. The expectation of life at birth is also known as the "mean duration of life." The probable duration of life is the age at which a given number of children born at the same time will be reduced to half the number. For males this is 51·2, and for females 56·7.

In order to construct a life-table, it is necessary to have (1) a census population, showing relative proportion of males to females at various age-periods; (2) death-returns for one or more years for the same population grouped according to the same age-periods. From these data it is possible, by means of mathematical calculations, to arrive at the figures shown in the various columns of the life-table. The following

abridged life-table shows the expectation of life at various ages:

ENGLISH LIFE-TABLE BASED UPON MORTALITY STATISTICS OF 1891-1900 (TATHAM).

Age.	Males.				Females.			
	Survivors at each Age out of 1,000,000 born.	Expectation of Life.			Survivors at each Age out of 1,000,000 born.	Expectation of Life.		
		1891-1900.	1881-1890.	1838-1854.		1891-1900.	1881-1890.	1838-1854.
0	1,000,000	44·1	43·7	39·9	1,000,000	47·8	47·2	41·8
1	828,136	52·2	51·0	46·6	859,342	54·5	53·2	47·3
2	784,090	54·1	53·0	48·8	816,810	56·3	55·2	49·4
3	767,754	54·3	53·3	49·6	800,357	56·5	55·5	50·2
4	757,631	54·0	53·1	49·8	789,683	56·2	55·3	50·4
5	750,281	53·5	52·7	49·7	782,144	55·8	54·9	50·3
10	734,299	49·6	49·0	47·0	765,267	52·0	51·1	47·7
15	725,373	45·2	44·5	43·2	755,499	47·6	46·5	43·9
20	711,714	41·0	40·3	39·5	741,766	43·4	42·4	40·3
25	693,894	37·0	36·3	36·1	725,386	39·4	38·5	37·0
30	673,200	33·1	32·5	32·8	705,819	35·4	34·8	33·8
35	648,169	29·2	28·9	29·4	682,147	31·5	31·2	30·6
40	615,964	25·6	25·4	26·1	653,014	27·8	27·6	27·3
45	577,010	22·2	22·1	22·8	619,184	24·2	24·0	24·1
50	530,888	18·9	18·8	19·5	580,320	20·6	20·6	20·7
55	475,849	15·8	15·7	16·4	533,105	17·2	17·2	17·4
60	409,518	12·9	12·9	13·5	473,037	14·1	14·1	14·3
65	332,344	10·3	10·3	10·8	398,299	11·3	11·3	11·5
70	246,630	8·0	8·0	8·4	307,168	8·8	8·8	9·0
75	158,608	6·1	6·1	6·5	210,688	6·7	6·7	6·9
80	82,298	4·6	4·5	4·9	118,068	5·0	5·0	5·3
85	31,323	3·4	3·3	3·7	49,925	3·8	3·7	4·0
90	7,724	2·6	2·4	2·8	14,330	2·9	2·7	3·0
95	1,059	1·9	1·7	2·2	2,494	2·2	2·0	2·3
100	68	1·5	1·2	1·7	241	1·8	1·5	1·8

Value of Statistical Facts and Methods.—It is a commonplace remark that statistics can be made to prove anything. This, of course, is the reverse of the truth; but, still, to be of value, and suitable for analysis, statistics must, as far as possible, be prepared with attention to the following data: (1) The facts or numerical units must be correct and comparable, and (2) must be numerous enough, and extend over sufficient length of time, to give correct averages. The limit

of variation existing between the units of a series may be obtained by the use of Poisson's formula:

Let M be the total cases in the series;
m be the number in one group;
n be the number in the other group.

The proportion of each group to the whole series is $\frac{m}{M}$ and $\frac{n}{M}$, and the extent of the variations in these proportions in succeeding series will be within the limits expressed thus:

$$\frac{m}{M}+2\sqrt{\frac{2\ mn}{M^3}}$$

and

$$\frac{m}{M}-2\sqrt{\frac{2\ mn}{M^3}}.$$

Example.—Of 100 cases of diphtheria treated, 70 recovered and 30 died. What was the limit of variation, and what would this be in a larger series of 2,500 cases ?

Error in first series $=2\sqrt{\frac{2\ mn}{M^3}}=2\sqrt{\frac{2\times 70\times 30}{(100)^3}}=\cdot 13$ to unity, or 13 per cent.

In other words, the number of recoveries in a second series might be 83, or 51 per cent.

The relative value of two or more series varies inversely as the square roots of the number of units in the respective series.

Therefore in the above example—

$$\text{Error in first series} : \text{error in second series} :: \sqrt{\text{No. of cases in second series}} : \sqrt{\text{No. of cases in first series}}$$

In second series let $x=$ error:

$$\text{Then, } 0{\cdot}13 : x :: \sqrt{2500} : \sqrt{100}$$

$$x=\frac{0{\cdot}13\times\sqrt{100}}{\sqrt{2{,}500}}=\frac{0{\cdot}13\times 10}{50}=0{\cdot}026 \text{ to unity, or } 2{\cdot}6 \text{ per cent.}$$

In second series the recoveries might be

$70+2{\cdot}6=72{\cdot}6$
$70-2{\cdot}6=67{\cdot}4$ per cent.

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